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A PROPOSED CLASSIFICATION OF PETROLEUM AND NATURAL GAS FIELDS BASED ON STRUCTURE.[1]

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Although not necessary to take time *here* to give the history of the "anticlinal theory" in full; it seems desirable to point out several prominent features of that theory and of its history and practical application, before giving some of its limitations and stating the standing of the theory to-day. For over fifty years various geologists and others have published papers attempting to solve the problem of the distribution of oil and gas fields. Among others T. Sterry Hunt (1859 and 1863), E. B. Andrews (1861) and Hans Hoefer (1876) long ago recognized certain general relations of oil and gas pools to the anticlinal structure of a region. It remained for Edward Orton and I. C. White, however, to bring the theory before the oil and gas world in such a way as to force a measure of belief in it. Later investigations have expanded and limited the theory and have made its application more practical to the operators, but much of the credit belongs to the early investigators.

The anticlinal theory was, in brief, that oil and gas were originally widely disseminated throughout the formations in which they are found, or in contiguous formations, and their segregation was believed to be due to the different specific gravities of oil, gas and water. If a porous stratum contains these sub-

[1] Read before the Geological Society of Washington, March 9, 1910.

stances, when it is tilted by geologic causes they will arrange themselves according to specific gravity; the gas, being lighter, will be driven into the higher parts of the stratum (towards the crest of the anticline), the oil will be floated on top of the water, while the water occupies the lower portions of the stratum (those nearest the syncline).

Limitations of the Anticlinal Theory.—In practice, however, the anticlinal theory frequently did not meet expectations. Operators, after making careful locations of wells based upon this theory, were frequently rewarded only by dry holes. The successes, overshadowed by the fancied failure of the theory, were lost sight of by practical oil men, and thus the theory fell largely into disrepute for a time. The reports of the United States Geological Survey and the various state geological surveys throughout the country contained references to the theory, and each writer tried to show the geological relation of fields in the particular territory covered. In many cases geologists were successful in finding such a relation, and in all cases the major axes of pools were found to correspond *in a general way* with the main anticlinal and synclinal axes. Many of the gas pools corresponded closely with the crests of anticlines and seemed to prove the theory. Other cases prevailed, however, in which the relation was less striking and there were some in which no relation could be determined.

To explain the defects of the theory, various so-called "limitations" were formulated. The limitations, like the original theory, were imperfect in their application. They have been added to and rehashed by various geologists, until now little seems to be left of the original "anticlinal theory." However, great advances have been made consequent upon detailed mapping of geological structure by government surveys and private geologists. While we have not yet reached, and may never reach, the state where a production can be located correctly every time, we may truthfully assert that geology can now save a considerable proportion of dry holes. Moreover, much of the territory held for years by oil and gas companies has been shown to be not worth paying rentals on.

Statement of the Structural Theory.—The writer of this paper prefers to use here the term *"structural theory"* instead of "anticlinal theory" to explain the relations which accumulations of oil and gas hold to geology within certain limitations, *even where no definite anticline or syncline exists.* The theory, as understood, is as follows: Through some means or other, by organic or inorganic agencies, or by both, the petroleum and gas have got into the sandstone or limestone formations in which they are found. The deposits may have originated through the decomposition of plant and animal remains on an ancient sea bottom, as the adherents of the *organic theory* claim. Or they may be the product of chemical action on carbides of iron or other substances existing under a state of potential fusion deep in the earth, as the adherents of the *inorganic theory* claim. Or certain petroleum deposits may be of organic and certain deposits of inorganic origin, which seems a conservative opinion.

Whichever theory be true, the oil, gas and water in the formations (assumed to have been approximately horizontal at the time the substances entered them) were at first widely diffused in the oil sands or contiguous strata. Such is true at the present time in some sections of the world, notably in several counties in western West Virginia fronting on the Ohio River, where only small quantities of oil and gas, too slight for profitable development, have been found. The dip of the rocks in that section is very slight.

Where the beds have been folded, however, as is the case throughout the greater part of the Appalachian region and in most of the other oil fields of the world, the slope and changes in dip have enabled the oil, gas and salt water to separate out according to their relative specific gravities. This separation and concentration may have been assisted by rock pressure, hydraulic pressure, seepage, capillarity, molecular attraction, internal heat and other causes; but *whatever causes prevailed,* the law of gravitation, being ever operative, must be considered of most importance, and the separation and subsequent accumulation was in the order of the densities of the substances. Thus on a stated anticlinal, monoclinal or quaquaversal structure, the

gas is nearest the top, the oil lower down, and still lower is the salt water, when that is present. All this is according to the original "anticlinal theory." Sometimes the pools occur at the top of the anticlines, sometimes lower down on them, sometimes in synclines, sometimes merely on monoclines.

Convergence of Formations.—One of the mistakes of the earlier geologists and oil men was the assumption that the surface formations were universally parallel with the oil "sands."[1] This is true in many fields, but in others it is far from being so. For example, the Clinton sand in southern Ohio is not even approximately parallel with any surface formation; but the interval between the Clinton and the surface strata increases toward the east at a rate ranging from 30 to 100 feet per mile, thus bringing the Clinton rapidly to a great depth. This convergence was illustrated by Orton, Volume VIII. of the "Geology of Ohio," but it is now known to be less uniform and in places more marked than Orton supposed.

With the assistance of a few well records within a few miles of any locality, where development has been commenced or testing done, it is possible to work out the structure of this sand to a good degree of accuracy. This is done by first making a contoured structure map of some surface formation; then the exact intervals from this stratum to the Clinton sand are determined in whatever wells have been drilled to this sand in the vicinity, and a convergence map is prepared on the same scale. This was first done, so far as I know, by the writer of this paper, for the Amity, geological folio, and for Bulletin 300 of the United States Geological Survey, in 1907, and the name *isochore lines* (meaning lines of equal interval) was given to the contour-like lines denoting the convergence. Fig. 52 is an example of such a map from Bulletin 300. In the Amity region, however, the interval represented was that between the Pittsburg coal and the Gantz (or Hundred foot) sand, the Clinton sand never having been reached so far east. In Bulletin 318 of the United States Geological Survey the same method of representing con-

[1] In this paper the word "sands" is used, being the well-drillers' term for the productive formations.

vergence was used by Griswold and Munn, who applied the simpler, and perhaps preferable, name "convergence sheet" to maps of this type.

In preparing a map of the structure of the Clinton sand, of

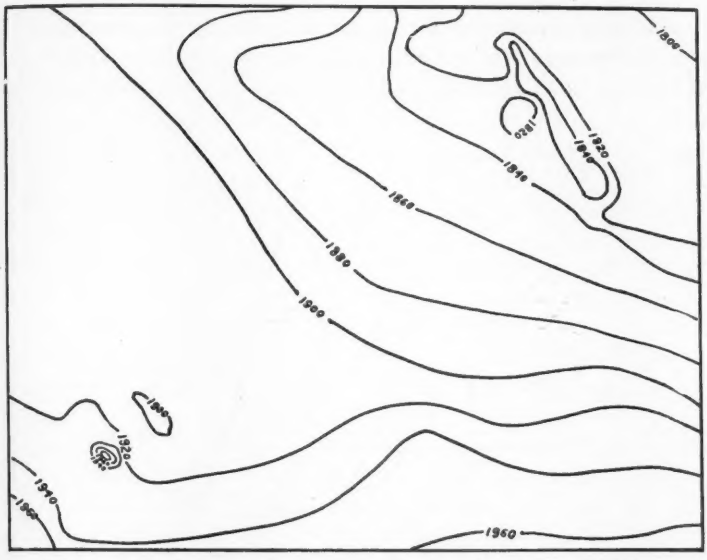


FIG. 52. Convergence map of the Amity quadrangle, in Washington County, Pa. The *isochore* lines (lines of equal interval) show the changes in interval between the Pittsburg coal bed and the Gantz sand throughout the quadrangle. (From Bull. 300, U. S. Geol. Survey, 1907.)

the formations below the Greenbriar limestone in southwestern Pennsylvania, and of certain other formations, a convergence map must be prepared. The necessity of this is due to unconformities. The convergence map is superposed on the contour map which shows structure of the surface formation, and the intervals represented by isochore lines are subtracted at every point, the resulting elevations of the sand being noted on an overlying tracing. The sand is then contoured. In practise the finished map always shows that the structure bears some defi-

nite relation to the occurrence of gas and oil. The direction of the extension of the field can therefrom be predicted with a good degree of certainty; and, if there has been no deep sand development, the locations of producing wells can be predicted with fair probability. Fig. 53 is a map of the Clinton sand in a small area in southern Ohio, where the structure was determined in this manner. It will be noticed that the positions of oil de-

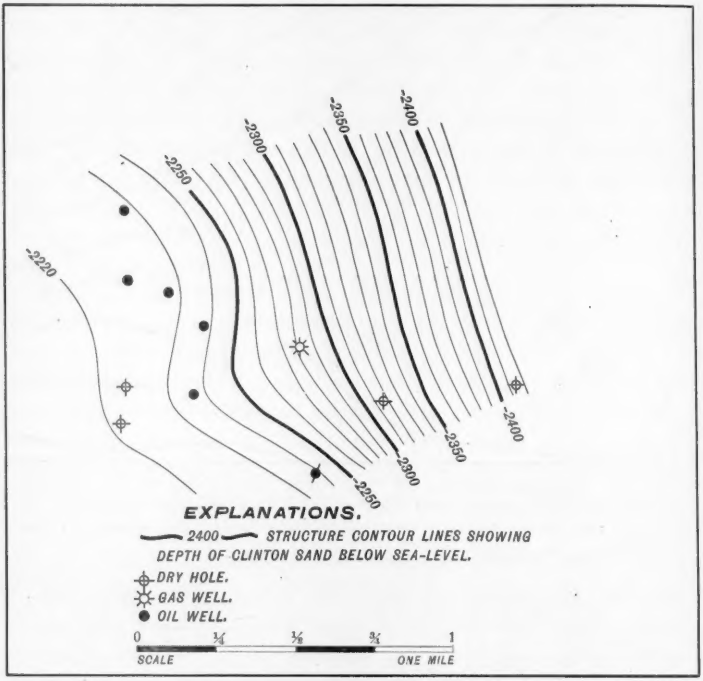


FIG. 53. Example of sub-class I(*c*). An oil pool coincident with a change in monoclinal dip, in the Clinton sand of southern Ohio. Structure map of the sand in a small area determined by the convergence method.

velopment correspond well with the strike of the sand, and that the productive wells lie on the outer edge of a slight structural terrace. Fig. 54 shows the surface structure at the same locality,

and illustrates the entire lack of agreement with the structure of the sand.

The foregoing summaries have been made because it seems necessary to take them into account in making any classification

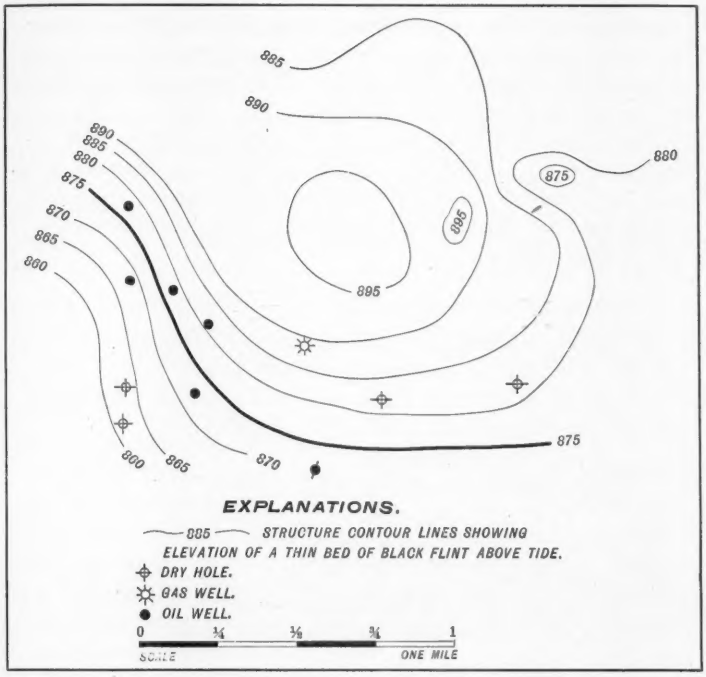


FIG. 54. Structure map of the surface formations in the same area as Fig. 53.

of fields based on structure. *The structure of the productive stratum itself must be considered independently of the configuration of structure of any surface formation.*

Classification of Oil and Gas Accumulations.—In order to illustrate the difference in geologic conditions, a tentative classification of fields has been made. Only accumulations of economic

importance are considered, and even some prominent fields, which the writer has not had opportunity to investigate, are not considered at all. The classification does not pretend to be perfect, by any means, and doubtless it has many deficiencies, but it is published here for whatever it may be worth as a geologic classification. There is no attempt made to distinguish oil structures from gas structures, nor between the different kinds or ages of productive formations. These could be brought in as subdivisions in the classification if desired.

The object of the tentative classification is to show that accumulations of oil and gas can be grouped into classes, each division of which follows a special rule of structure, and all of which have certain aspects in common. The classification proposed is as follows:

CLASSIFICATION OF OIL AND GAS ACCUMULATIONS.

I. Where anticlinal and synclinal structure exists.
   (*a*) Strong anticlines standing alone.
   (*b*) Well defined anticlines and synclines alternating.
   (*c*) Monoclinal slopes with change in dip.
   (*d*) Terrace structures.
   (*e*) Broad geanticlinal folds.
   (*f*) Overturned folds.
II. Domes, or quaquaversal structures.
III. Sealed faults.
IV. Oil and gas sealed in by asphaltic deposits.
V. Contact of sedimentary and crystalline rocks.
VI. Joint cracks.
VII. Surrounding volcanic vents.

Class I. Where Anticlinal and Synclinal Structure Exists.—This is the type of oil and gas accumulation with which we are most familiar. It includes a large majority of the known oil fields of the world. The Appalachian, Mid-Continent, Illinois, Indiana, Wyoming, Colorado, northern Louisiana and northern Texas, and some of the California fields in this country, and the Russian, Austrian, Burma and Borneo fields in the eastern hemisphere, all belong to this class. It is divided into five sub-

classes, in order to distinguish between various structural relations in which oil is found in connection with anticlines and synclines.

Subclass (a). Where Strong Anticlines Exist Standing Alone.—In this division I would include fields that bear a direct relation to *very pronounced* uplifts, easily recognizable, and which constitute a marked geologic feature of the region. The only prominent example in the eastern fields of the United States is the famous Eureka-Volcano Burning Springs anticline in West Virginia, which is 25 miles in length, ranging in direction from North 10 degrees West to North 20 degrees East, being from an eighth of a mile to half a mile broad on its flat crest, and having side-dips of from 20 to 60 degrees. This differs somewhat in direction from the main Appalachian folds, and was probably produced at a different time. It is one of the earliest recognized anticlines in the country, and probably has had as many wells drilled on it as any other anticline. It has been described by White,[1] Andrews and Evans. Some of the California fields having sharp anticlines probably belong in this class. Possibly the Baku field of Russia may also belong here.

Subclass (b). Where Well-defined Alternating Anticlines and Synclines Exist.—This is really a composite of subclass (*a*). With minor exceptions it includes the entire Appalachian field in Pennsylvania, West Virginia, and eastern Kentucky, southern Indiana and Illinois, the Oklahoma fields and the Caddo field in Louisiana, the north Texas fields, and those of Colorado, Wyoming and Montana.

The Caddo field has nothing in common with the Beaumont and Jennings fields and other fields of the Coastal Plain of Louisiana and Texas, but it is very similar in structure to the fields of Pennsylvania, West Virginia and Illinois. The proper structure in northern Louisiana is afforded by the Sabine uplift. The final distribution of oil and gas in the Caddo field is presumably due to slight anticlines and synclines and differences in porosity of the Upper Cretaceous formations which exist there.

[1] I. C. White, *Bull. Geol. Soc. Am.*, Vol. 10, 1899, pl. 29.

Several of the oil fields of California also belong in this class. Examples are Coalinga field and the Los Angeles field,

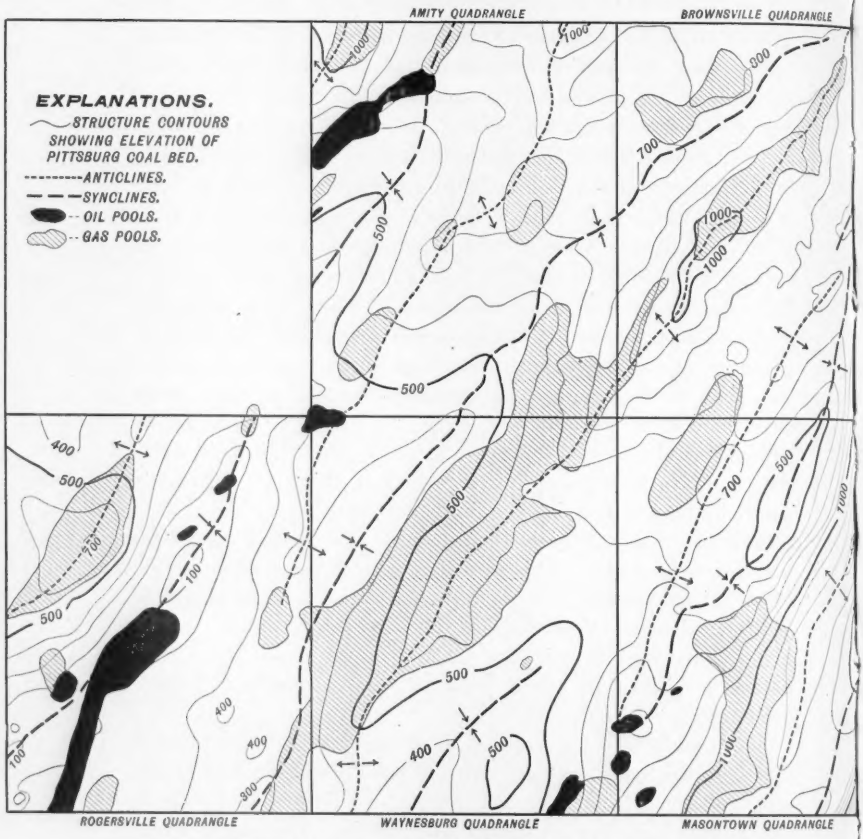


FIG. 55. Example of sub-class I(*b*). Structure of five quadrangles of the U. S. Geological Survey in southwestern Pennsylvania, showing relation of the oil and gas pools to surface structure. (After Campbell, Stone and Clapp.)

according to description by Eldridge,[1] and by Arnold and Anderson.[2] In 1895 Noettling established the fact that the oil fields

[1] Geo. H. Eldridge, Bull. 213, U. S. Geol. Survey, pp. 306–321, 1902.

of the Irawaddy, in Burma, correspond with the structural theory; and I believe they belong in this subclass. The oil and gas in those fields are directly related in their accumulation to anticlines and domes in the Miocene sandstone.

The rocks in the fields comprised in subclass (*b*) are folded into alternating anticlines and synclines, bounded by moderate dips, seldom more than 30 degrees from the horizontal. This is the subclass to which the anticlinal theory as originally propounded applies strictly; the gas occurs in the upper part of individual sands or "pay streaks," the oil occurs somewhere below the gas, while salt water, if it occurs at all, fills in the remaining space in the sand (if the latter is uniformly porous), or occurs in the separate "pays" (where the sand as a whole has not a high degree of porosity), all these deposits being controlled mainly by the force of gravity. Where oil or salt water occurs higher in the sand than gas, it is presumably due to sharp changes in the dip, or to a multiple nature of the "pay streaks."

Subclass (*c*). *Where there are Monoclinal Dips; i. e., where the Rocks Dip in one General Direction Throughout* (*Although the Dip may Vary in Steepness*).—The majority of the oil and gas pools in southeastern Ohio belong in this division. Definite anticlines are not so common in Ohio as in Pennsylvania and West Virginia, as the prevailing dip of the formations is all in one general direction (towards the southeast). However, the application of the structural theory, properly understood, is almost as certain of profitable results as it is in Pennsylvania, because the dip is not uniform, but varies from flat to over 5 degrees from the horizontal. Rounded or somewhat elongated semi-anticlines of subclass (*b*) are occasionally found.

Oil and gas can be predicted in subclass (*c*) through recognition of the principle that any change in the rate of dip is to be considered as a possible place of accumulation; and that such a place of accumulation once discovered, the pool can be easily extended (within structural limits) by following lines of horizontality in the sand. Subclass I(*c*) is illustrated in Fig. 53.

[2] Ralph Arnold and Robert Anderson, Bull. 357, U. S. Geol. Survey, pp. 70–71, 1908.

To this subclass may also belong (in part at least) the Florence oil-field in Colorado, where the oil exists in beds having a dip of less than 5 degrees, lying between dips as great as 20 degrees (according to Fenneman,[1] and occupying a portion of a structural slope where the sands locally are rather flat for a few miles; being a semi-terrace in the formation. In this field the beds carry little water.

Subclass (d). Terrace Structures are an Exaggerated Form of the Flattenings of Dip, Included in Subclass (c).—As a rule where gas occurs, it is found on the outside of the terrace and oil on the inside, though this is not an infallible rule. The change in the rate of dip, forming a local interruption, seems to be the essential factor. An example of a structural terrace in southwestern Ohio is shown in Fig. 56.

The effect of terrace structure was first explained and illustrated by Edward Orton in 1886.[2] The terraces described by him were in the Trenton limestone fields of northwestern Ohio. In the Findlay field the oil and gas were found in two terraces, separated by a monoclinal dip. The upper terrace yielded dry gas, the lower terrace yielded oil and water.

Orton gave the name "arrested anticlines" to structural terraces, and cites the Macksburg field of southern Ohio as an example.[3] The terrace structure of the Macksburg field was first recognized and described by Newhall in the same volume.

During the past decade hundreds of similar terrace structures have been discovered throughout southeastern Ohio and to some extent in adjacent states, and most of them are available for oil and gas development. Generally, though not always, the structure can be determined from the geology of the surface without the need of borings until one is ready to make his test. Other good examples of terrace structures and the relations of oil to them were shown by Griswold and Munn in Jefferson Co., Ohio.[4]

[1] N. M. Fenneman, Bull. 260, U. S. Geol. Survey, 1904, p. 437.
[2] *Science*, Vol. 7, p. 563.
[3] "Geology of Ohio," Vol. 6, p. 94, 1888.
[4] Bull. 318, U. S. Geol. Survey, 1907.

Subclass (e). Broad Geanticlinal Folds.—This is an extreme type of I(*a*). By a geanticline is meant an anticline which is extremely long and broad, and constitutes more than a local feature, extending over thousands or tens of thousands of square

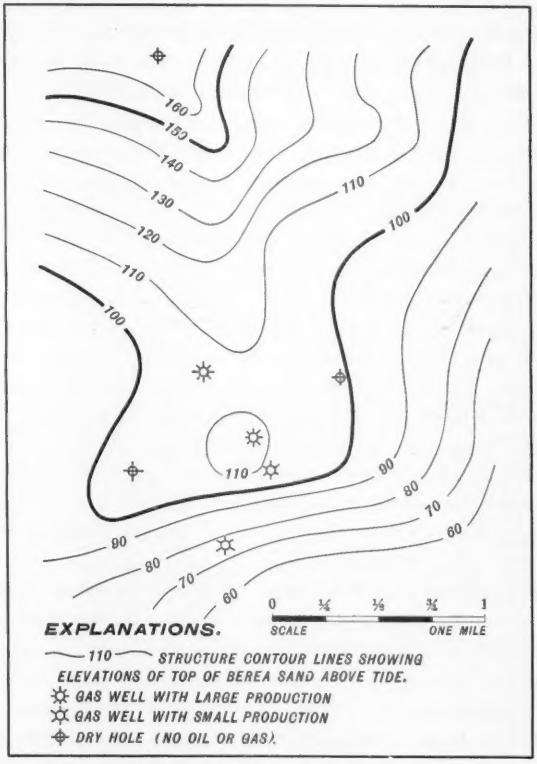


FIG. 56. Example of subclass I(*d*). A gas pool coincident with a structural terrace, in the Berea sand of southeastern Ohio.

miles. One of the best examples in this country is the Cincinnati anticline, in which immense reservoirs of oil and gas have been developed and exhausted, the oil and gas being contained mainly in the Trenton limestone. Owing to the broad areas

under which oil and gas are found in the Cincinnati anticline the chances of success in drilling were originally much better than in other fields. The decline of the Trenton limestone fields was largely due to wastefulness of the gas before people in general understood that the fields were subject to exhaustion. Most of the pools in the Clinton sand in Ohio are situated along the eastern flank of the Cincinnati anticline, but these pools belong under subclasses (*c*) and (*d*), of the classification.

Subclass (*f*). *Overturned folds.*—Examples of oil and gas occurring in connection with overthrust folds are not common but some such cases are conspicuous in California, as shown by Arnold and Johnson.[1]

Class II. Domes, or Quaquaversal Structures.—Certain types of *anticlines* developed as well-marked domes might be classed here; but since they are included in subclasses (*a*) and (*b*) of Class I., the domes here considered will be limited to those which are not part of any well-developed anticline, and are thus susceptible of a different classification. The conspicuous examples of the occurrence in this country are in the fields of the Coastal Plain of Texas and Louisiana, described by Hayes,[2] Kennedy,[2] Fenneman,[3] Harris[4] and others. Some of the best known instances are Spindletop, Sour Lake and Batson. The mounds in which gas and oil exist may not show as such at all on the surface. They do, however, appear *in some cases* as circular elevations covering several hundred to several thousand acres and rising 50 to 100 feet above the surrounding plain, in which case they can, of course, be easily recognized. They are frequently known as "salines," on account of containing deposits of rock salt. Underneath the surface the whole body of strata have a mound-like shape, containing, in addition to the ordinary formations, limestone, salt, gypsum, and other minerals, all of which have been pressed upwards in approximately circular outlines.

[1] Ralph Arnold and Harry R. Johnson, Bull. 406, U. S. Geol. Survey, 1901, p. 97.

[2] C. W. Hayes and Wm. Kennedy, Bull. 212, U. S. Geol. Survey, 1903.

[3] N. M. Fenneman, Bull, 282, U. S. Geol. Survey, 1906.

[4] G. D. Harris, Geol. Survey of La., Bull. No. 7, 1908.

Fig. 57 shows a cross section of a typical saline according to the ideas of Harris.

Class III. Along Sealed Faults. The known examples of this class consist of some of the pools in the Los Angeles field and some of those in the Lompoc field in California described by Arnold.[1] In these cases the highly inclined oil sands are cut off abruptly below ground by a fault, thus sealing in the oil and gas and preventing their escape to the surface. An example

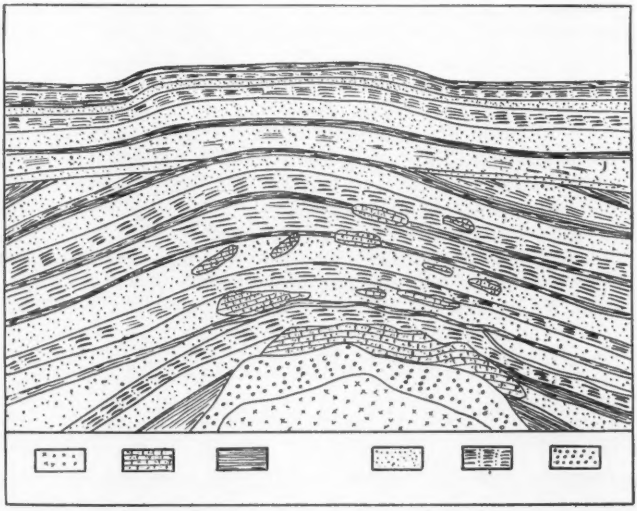


FIG. 57. Example of class II. Typical cross section of mound in Texas and Louisiana. (After Harris, Geol. Survey of La., Bull. No. 7, 1907.)

of this class is given in Fig. 58. Some of the other oil fields in California probably belong in this class. To show the probability that such cases are more frequent than known, it may be worth while to mention that oil-springs frequently, and perhaps generally, occur along fault lines. Some of these instances exist in British Columbia and others in Gaspe, Quebec.

Class IV. Oil and Gas Sealed in by Asphaltic Deposits.—Cer-

[1] Bull. 309 and 322, U. S. Geol. Survey, 1907.

tain examples of this class, like the last, are few, and not well known, but they may be exemplified by the Pitch Lake of Trinidad, where small quantities of oil and gas are reported. Some of the oil found near the vein of grahamite at Ritchie Mines, West Virginia described by White,[1] may belong in this class, although these deposits are also dependent in their original accumulation upon anticlinal and synclinal structure, as in Class I.

Class V. At the Contact of Sedimentary and Crystalline Rocks.—The principal known examples of this class are in the

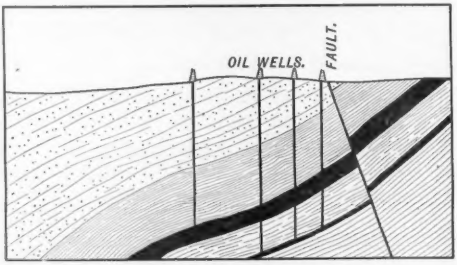


FIG. 58. Example of class III. An oil pool in California sealed in by a fault line. (After Arnold, Bull. 309, U. S. Geol. Survey, Plate 20, 1907.)

Provinces of Quebec and northern Ontario, and have not been much studied. It is probable that gas occurs at some places in northern New York state in this way. No records are at hand of *oil* occurring in such a position, but gas occurs in commercial quantities. It is held in the zone of the lower Potsdam sandstone which is of arkose nature, and rests directly upon the underlying granite. The deposits seem, so far as the writer has been able to learn from men who know the fields, to occur on top of prominent knobs of the granite. The occurrence may be somewhat as in Fig. 59.

Class VI. In Joint Cracks.—According to descriptions of Mr. H. S. Gale, some of the oil in the Florence field in Colorado occurs in joint cracks in shale. Other examples of this nature are believed to exist elsewhere.

[1] I. C. White, Bull. Geol. Soc. Am., Vol. 10, 1899, pp. 277–284.

Class VII. Surrounding Volcanic Vents.—This class seems to be illustrated by certain Mexican fields. It may be considered an exaggerated form of Class II.

Although most fields are susceptible of classification according to the foregoing plan, some of them do not fit in easily. It is believed that if all the causes and effects, and the internal

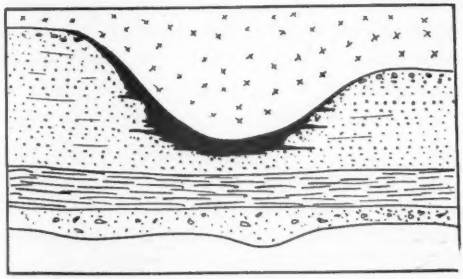


FIG. 59. Theoretical example of class V. A gas pool in the arkose zone between granite and Potsdam sandstone, in Province of Quebec.

character of the sands, were known in every case, the fields could be classified. Another factor of importance in the position and distribution of all types of oil and gas accumulations is the degree of saturation of the sand; although, as has been explained,[1] the position of the water line is not so important as some persons have supposed. In the Berea grit, for instances. many pools have been found, and are still being tapped, where the oil lies below the water line in neighboring pools in the same sand.

Some of the newer oil developments have taught lessons which operators and geologists took years to learn, but now that they have been learned, they are being productive of good results. For instance, in pools where the oil occurs in thin "pay-streaks," there are sometimes dry areas several square miles in extent, which lie directly "down-dip" from important pools of oil or of water or of both. Near the corner of Brighton, Chippewa and South Beaver townships, in Beaver County, Pa.,

[1] ECON. GEOL., Vol. IV., 1909, pp. 565–570.

is a small pool in which the production of the wells is very light, which is bordered on the northeast, southeast and south by a number of strong salt water wells. The "pay" here, as in the majority of pools in the Berea sand, is near the top of the sand. The salt water in close proximity to the pool occupies a definite structural position with reference to it, occurring on all sides of the pool except on the up-dip side. However, this water was not found to extend far down-dip from the oil-pool, several wells between there and the Ohio River, four miles southeast, having been dry of both water and oil. Similar occurrences are found repeatedly in the Berea sand in Beaver County, Pa., and in neighboring counties and the Pan-Handle of West Virginia and in Ohio, where dry areas of the sand occur on the down-dip sides of several pools of oil and salt water.

The point to be noted is that the lowest oil-pool in a stated group of pools in the Berea sand is successively higher above sea-level going from southwest to northeast parallel with the Ohio River. Near Steubenville and Mingo, in Jefferson County, O., the lowermost elevation at which oil has as yet been discovered in this sand is 600 feet below sea-level; at Holidays Cove, W. Va., it is about 400 feet below sea-level; on the West Virginia-Pennsylvania line near the southwestern corner of Beaver County it is 250 feet below; at Hookstown and Smiths Ferry, Beaver County, it is at sea-level; while near the corner of Brighton, Chippewa and South Beaver townships, in the pool first mentioned, it is 200 feet *above* sea-level. The progressive rise toward the northeast is explained in part by the greater general height of the anticlinal folds and the lesser depth of the adjacent synclinal depressions in the sand in that direction.

The fact that a so-called "pay-streak" lying down-dip from a known pool may be dry of both water and oil does not disprove the "structural theory" of the accumulation in its proper application; but the position of the dry area is due to the fact that whatever water and oil may once have occupied the "pay-streak" have been drained out, segregated elsewhere naturally or artificially, or that the "pay-streak" is in reality not so porous as

would seem from the size of the grains in the sand-pumpings. Moreover, many apparently dry areas are due to a change in the character of the sand, by which it becomes practically non-oil-bearing or non-water-bearing.

The fields in the deeper sands frequently do not correspond structurally with those in the shallow sands, even where the sands are parallel, and this is one reason why the deeper fields are not discovered more rapidly. As a rule, the shallow sands are productive of gas near the crests of anticlines, where anticlines occur, as in Classes I(a) and I(b), and are frequently confined to domes, in these crests, *while the deeper sands may* be, and frequently *are,* barren on the crests and productive of gas on the flanks of the anticline where it is dipping moderately steeply towards the adjacent syncline. This is generally due to the non-parallelism of the deeper sands. And since the size of pools is approximately inversely proportional to the steepness of the dips, these deep-sand pools commonly take the longest to be discovered by the drill.

ANHYDRITE AS A GANGUE MINERAL.[1]

WALDEMAR LINDGREN.

About three years ago Mr. V. C. Heikes, of the U. S. Geological Survey, called my attention to some interesting specimens from the Cactus mine in Beaver County, Utah, showing the intergrowth of gypsum in large transparent flakes with entirely unaltered chalcopyrite. In the spring of 1908 I had the opportunity of visiting the locality and found in brief that the gypsum is an alteration product of anhydrite, the anhydrous calcium sulphate, and that the latter mineral at this mine forms one of the important gangue minerals. I can not find that any similar occurrence has thus far been reported from the United States.[2]

The Cactus mine is the property of the Newhouse Mines and Smelter Corporation, now reorganized as the South Utah Mine and Smelters Corporation. It is situated in the San Francisco Range, one of the many desert ranges of southern Utah and well known to mining men since the early period of mining in Utah as the location of the famous Horn Silver mine. The district was described briefly by S. F. Emmons in 1905.[3] The geological features of the range consist of a thick series of limestones and quartzites of early Paleozoic age, intruded by a large mass of coarse-grained monzonite. The Cactus mine lies on the western slope of the range and has been known for many years although its extensive development as a large low-grade copper property dates only a few years back. The deposit of the Cactus mine lies in the northern part of the monzonite area, but the limestones appear only about 1,500 feet to the north of the property. The

[1] Published with the permission of the Director of the U. S. Geological Survey.

[2] A preliminary notice of the discovery of anhydrite at this place was published in *Science*, N. S., vol. 28, Dec. 25, 1908.

[3] S. F. Emmons, "The Cactus Copper Mine, Utah," Bull. U. S. Geol. Survey, No. 260, 1905, pp. 242–248.

principal mineralized area extends for a length of about 900 feet at the surface and varies in width from 90 to 200 feet; its direction is N. 30° W. The deposit forms a stockwork within which the monzonite is crushed and shattered.

The mine is opened by extensive surface workings and by a tunnel 6,000 feet long, through which the ore is now extracted. This tunnel is driven through monzonite and strikes the nearly vertical deposit 600 feet below the outcrop. Below the adit level an incline is sunk to a vertical depth of 316 feet from which the seventh, eighth and ninth levels are opened. During the fiscal year ending June 30, 1908, the company extracted 176,766 tons of ore, of which all but 10,000 tons was milled, yielding 19,376 tons of copper concentrate. A total of 7,244,179 pounds of copper, 1,721 ounces of gold, and 38,595 ounces of silver were produced. The ore is thus of low grade, but the copper could be produced at small cost.[1]

The principal ore is chalcopyrite; much pyrite is associated with it, but galena and zincblende occur only exceptionally. The mine contains little water and the zone of oxidation of the chalcopyrite has only a superficial depth. At many places the sulphides are found within a few feet of the surface. A little chalcocite is found in spots in the upper levels and occasionally also bunches of tetrahedrite rich in silver.

To a large degree the ore occurs as a cement of the monzonite breccia but is also found disseminated throughout the rock. The principal ore minerals have already been mentioned; the gangue consists of tourmaline, siderite, specularite, anhydrite and gypsum. The tourmaline is abundant, though not equally distributed throughout the deposit. Its most common occurrence is as a crust of well developed black needles or radiating bunches surrounding the sericitized fragments of monzonite, but the mineral is also frequent in the seams and joints throughout the stockwerk. The quartz is, on the whole, later than the tourmaline and forms well-developed crystals, which, like the tourmaline,

[1] V. C. Heikes, "In Mineral Resources U. S. for 1908," U. S. Geol. Survey, 1909, p. 554.

encrust the fragments and often enclose delicate needles of the tourmaline.

Gypsum, anhydrite, siderite and specularite are found in considerable quantities, but of these the gypsum is probably the most abundant; it penetrates in fact the whole stockwork in abundant seams and in places fills new fissures up to about one foot in width. Anhydrite is found in closest association with gypsum from the second level down to the bottom, and, wherever it appears, it in process of alteration to gypsum; from the relations of the two minerals it is confidently believed that all of the gypsum is an alteration product of anhydrite. The hydration takes place readily, long before the rock is attacked by oxidation. At the surface neither gypsum nor anhydrite are visible. Anhydrite, siderite and specularite were formed at a somewhat later stage than the quartz and tourmaline and form the filling of the interstices in the breccia as well as in the numerous seams in the altered rock.

The anhydrite, when fresh, forms crystalline masses, the individuals of which are sometimes several centimeters in length; the rough crystals may have a cubical or more commonly a flat tabular form. The color is a characteristic pale violet or purple. The three planes of cleavage are perpendicular to each other, but are of a somewhat differing degree of perfection. The mineral has probably been taken for calcite or fluorite. Polished pieces show very clearly the incipient development of gypsum in seams, parallel to the cleavage or traversing the mineral irregularly. An approximate analysis of the mineral by Dr. W. T. Schaller gave 39.84 per cent. lime, 55.89 per cent. sulphuric anhydride and 3.57 per cent. loss on ignition. The optical characteristics correspond closely to those of anhydrite; the refraction is moderate, the double refraction high, contrasting strongly with the much lower double refraction of the gypsum seams.

The siderite and specularite were evidently deposited together with the anhydrite; the former appears as pale brownish crystalline aggregates.

The pyrite is in part crystallized in the usual combination of

cube and pentagonal dodecahedron; it is intergrown with all of the previously mentioned gangue minerals and also develops in finely divided form in the country rock near the deposit. The chalcopyrite ordinarily forms irregular masses and its deposition seems to have begun at an early stage simultaneously with or immediately following the deposition of tourmaline. More abundantly, however, it is intergrown with anhydrite, quartz and siderite, but it is mainly later than these minerals; in some places it fills the interstices between well-developed crystals of anhydrite, of rectangular cross section; equally often it is found surrounding quartz crystals and also occurs intimately intergrown with pyrite. Its formation, therefore, began early and continued to the close of the epoch of mineralization. A frequent mode of occurrence of the chalcopyrite is also as thin lamellæ between the cleavage planes of the anhydrite.

Anhydrite is, as well known, abundant in certain sedimentary formations in which it was deposited together with strata of gypsum and rock salt. For a long time this anhydrite was thought to have been derived by dehydration from strata of gypsum, but in 1901 Van t'Hoff[1] showed that in solutions of sodium chloride at 30° C. anhydrite may be precipitated as such. A search of the literature revealed the fact that anhydrite has been found in some mineral deposits of Europe. It is mentioned[2] from Kapnik in Hungary, Andreasberg and Lauterberg in the Harz Mountains, Reichelsdorf in Hessen, Bleiberg in Carinthia, and Fahlun in Sweden. At Andreasberg it occurs in calcite veins; at Lauterberg it was observed in veins containing copper and lead ores in Paleozoic slates and sandstones; together with it are found barite, calcite, quartz and gypsum.

The peculiar association of native gold embedded in gypsum has been recorded from several places, notably from the Old Abe mine in New Mexico and several gold mines in Transylvania. Mr. L. C. Graton, who has visited the former locality, believes that the gypsum is here derived by hydration from anhydrite and the same explanation may well apply to the Transyl-

[1] *Sitzber. Berl. Akad.*, 1901, pp. 570 and 1140.

[2] Max Bauer, "Lehrbuch der Mineralogie Stuttgart," 1904, p. 847.

vanian occurrences. A close search will probably show that anhydrite is more commonly present in mineral deposits than has been expected.

In the present case the association of tourmaline, quartz, anhydrite and siderite is certainly unusual and can not well be explained by derivation of the calcium sulphate from sedimentary formations. At the Cactus deposit the coarse-grained monzonite is intrusive into Paleozoic sediments which at many places near the contact are extensively converted into garnet and tremolite with simultaneous development of chalcopyrite. It is plain that the deposit was formed after the consolidation of the intrusive magma, and the presence of tourmaline suggests that the deposition took place at high temperature and pressure, which later were diminished so as to permit the development of the carbonates and sulphates. It is very unusual to find an associa- later were diminished resulting in the development of carbonates and sulphates. As far as our experience goes, the sulphates of the earthy minerals ordinarily belong to deposits formed near the surface. A few instances have been recorded in which tourmaline was deposited together with siderite.

If the ores at Cactus were formed by ascending solutions, as seems probable, an unusually large amount of sulphuric acid must have been supplied by the intrusive magma. Regarding the lime there is a possibility that it has been supplied from the limestones which once, before the present period of erosion, must have covered the intrusive batholith. It is suggested as a possibility that during the later part of the mineralization the anhydrite was precipitated by a reaction between ascending solutions of sodium sulphate and descending solutions containing calcium carbonate.

In this connection some recent experiments on the solubility of calcium sulphate at high temperatures by Melcher are of great interest.[1] He finds that above 100° C. the solubility of anhydrite decreases extremely rapidly so that at 218° C. the solu-

[1] Arthur C. Melcher, "The Solubility of Silver Chloride, Barium Sulphate and Calcium Sulphate, at High Temperatures," *Jour. Am. Chem. Soc.*, Vol. 32, No. 1, 1910, pp. 50–66.

bility is of the same order of magnitude as that of barium sulphate, which slowly increases its solubility with increasing temperatures. Expressing his solubilities in milli-equivalents per liter Melcher finds that the solubility of gypsum at 18° C. is 29.5, while that of anhydrite is 9.2 at 100°, 2.7 at 156°, and only .7 at 218°. Expressed in the same terms the solubility of barium sulphate is .0190 at 18° C. and .0334 at 100°.

These important results show that at high temperatures anhydrite is practically insoluble and this would, of course, promote its precipitation by a reaction such as suggested above.

The detailed work in the mining districts of the San Francisco Range was begun by Mr. B. S. Butler, of the U. S. Geological Survey, in the summer of 1908 and the field work completed in 1909; the problem here touched upon in its mere outline will be fully treated in his forthcoming report.

THE OCCURRENCE AND ORIGIN OF SOME BOG IRON DEPOSITS IN THE DISTRICT OF THUNDER BAY, ONTARIO.

ELWOOD J. MOORE.

While engaged in making an examination of some bog iron deposits in the district of Thunder Bay, Ontario, certain observations were made which may add something to our knowledge of the occurrence and origin of bog iron. As a detailed account of these deposits has already been given,[1] the present article will be restricted to those factors which bear upon the nature of the occurrence and origin of the iron.

The geological conditions in the region are similar to those described for the bog iron regions of Quebec and Sweden. The area is drift-covered and is situated in an Archean region where relief is low and the physiographic conditions cause sluggish and meandering streams, which here and there expand into small, swampy lakes. A heavy blanket of vegetation in the form of labrador tea and sphagnum moss covers the area and the slow movement of the water and the large supply of vegetation combine to produce two factors favorable for the production of bog ore, viz., an abundance of organic acids and plenty of time for them to act upon the minerals occurring in the drift.

HOW THE IRON OCCURS.

The iron occurs in both the ferrous and ferric conditions and as a combination of the two forms. The ferrous form exists in the state of a greenish salt, or salts of the protoxide, and the ferric form as the common hydrous oxide, limonite. The ferrous salts are in all probability the sulphate and silicate, chiefly the latter in combination with some organic salt or salts. The combination of the two oxides gives a small amount of magne-

[1] 18th Rept. of the Bureau of Mines, Ontario, 1909, pp. 180–195.

tite which doubtless has been deposited in the bog as a clastic sediment, as appearances lead one to that conclusion. It occurs in very small fragments which can readily be isolated with the magnet.

No carbonate of iron was detected, though special search was made for the salt because of the interest which is attached to it in the origin of the pre-Cambrian and other ores. According to Julien[1] the carbonate of iron is not formed in a bog near the surface, at the present day. It is, however, occasionally observed in bogs a short distance below the surface, when the decay of vegetable matter gives rise to carbon dioxide and where there is not a sufficient supply of oxygen to form the soluble humates with organic substances. Messrs. Cameron and Robinson[2] found by experiments that the ferrous carbonate was precipitated from a solution of a ferrous salt by an alkaline carbonate, but no definite ferric carbonate could be found to exist. They also found that under certain conditions, *e. g.*, when precipitated from boiled water, the ferrous carbonate was dirty green in color, and this suggested that some of the greenish salt mentioned above might be the carbonate, but none of the tests made showed any of this salt.

The limonite occurs in red, brown and yellow colors and forms either soft or hard, bedded masses, concretions, slimy mud or cement in sand. In the mud there is usually more of the ferrous salt than the ferric because the organic material, by formation of carbon dioxide, prevents the oxidation of the material carried into the bog in the ferrous condition and even reduces some of the ferric to the ferrous salts. This reducing action may readily be observed along the shore of the lakes where vegetable matter is present. Here the brown limonite concretions which have a thickness of eight or ten inches, become gradually dissolved away in the lower layers of the deposit and changed to a greenish salt. The gradual dissolution of the concretions may be observed with increasing depth and this condition is similar to that which is

[1] A. A. Julien, "The Geological Action of the Humus Acids," *Proc. Amer. Assn. for the Adv. of Sci.*, Vol. 28, p. 403.

[2] *Journal of Physical Chem.*, Nov., 1908, pp. 511 and 523.

found in the bogs of Quebec.[1] This greenish salt readily turns red on heating, through oxidation to hematite. As some manganese occurs in these deposits, a portion of the black and greenish colors is no doubt due to its presence in different forms.

An analysis by Mr. N. L. Turner of the yellow limonite which formed a layer about four inches thick, in water two feet deep gave:

	Per Cent.
SiO_2	35.17
Metallic iron	27.34
CO_2	absent
Loss on ignition	8.52

CONCRETIONARY DISCS OF ORE.

The most frequent occurrence of the iron is in the form of concretions, which assume various shapes, and possess a roughly spiral structure. To one used to camp life the disc-shaped forms immediately suggest dried apricots, while some of the forms more irregular in shape and more nearly equi-dimensional, strongly resemble dried prunes. The larger ones are usually concave and cake-shaped. They vary in size from half an inch to three inches in diameter and from one quarter to one half inch in thickness. These concretions are much smaller than the large ones found in Quebec or in New Brunswick, where, Chalmers[2] states, the larger cakes have a diameter as great as from two to three feet. They occur along sandy shores of the lakes, in shallow water, and extend a distance of two hundred yards from shore, but few of them were found in water more than two feet deep. They apparently owe their origin, to a considerable extent, to the presence of sand which forms nuclei for centers of crystallization. There is no doubt that some close connection exists between the origin of these concretions, the movement of sand by the waves and the depth at which the limonite will harden. It was observed that the iron was practically confined to the northern portions of the lakes and mostly to points or spits built by shore currents. This seemed to be

[1] "Geology of Canada," 1863, p. 511.

[2] Canadian Geological Survey, 1882–84, p. 46 G. G.

explained by the fact that the streams carrying the iron nearly all entered the lakes towards the north end and the prevailing winds in summer, when the iron solutions are doubtless most concentrated because of evaporation of water and increased activity of organic acids through the growth and decay of vegetation, blow from a southerly direction. Precipitation would then be aided by the rolling of the sand grains and it was found that scarcely any iron occurred where the beach was not sandy.

In the bottom of the lakes the distribution of the deposits was very irregular, as six or eight feet of iron-bearing slime occurred in the deeper water, in some places a thin layer of concretions in the shallow water, beginning where the mud left off and in other places yellow limonite occurred in shallow water. There was usually along the shore a bed of soft limonite and sand mixed with broken concretions, forming a layer from one to ten inches in thickness, and this layer was capped by a thin one of intact concretions. In the lower portion of the layer of broken concretions a green salt was generally conspicuous.

When the water in the lakes is low in the dry season considerable areas of concretions become exposed to the atmosphere and piled up by the waves along the water's edge. This deposit thins towards the lake and also landward.

A thin section was made from one of these concretions and another specimen was ground to a smooth surface, so its internal structure could be seen under the microscope. An examination of these specimens showed an opaque reddish-brown mass, which was not homogeneous, although no distinguishing feature beyond a finely porous condition, could be detected. In this mass were numerous angular, subangular or rounded fragments of quartz and a few of feldspar. There seemed to be no definite regularity in the orientation of the longer axes of the fragments, although in one case a roughly concentric arrangement could be observed. They were arranged either in bunches or as individuals scattered through the limonite groundmass. An analysis of some of these concretions made by Mr. N. L. Turner gave:

	Per Cent.
Silica (soluble)	8.92
Silica (insoluble)	4.88
Ferric oxide (Fe_2O_3)	68.36
Ferrous oxide (FeO)	2.16
Metallic iron	49.5

SOURCES OF THE IRON.

On entering this bog iron district a few conditions attract the attention of the observer. The chief of these are the unusually large muskegs, with their meandering streams and great quantities of vegetable matter, the presence everywhere of the sandy drift which apparently contains so little iron, and the red streams which deposit iron in the lakes and on almost every object they touch. The sand, which is the principal rock over which the waters flow, is made up chiefly of quartz and feldspar, the former devoid of iron and the latter also barren except for a little which may in some cases exist as coloring matter. Besides these two minerals there are minor amounts of biotite, hornblende, magnetite, pyrite, ilmenite, pyroxene and other iron-bearing minerals. Although the greater portion of the sand has come from the Laurentian granite, a considerable amount must have come from diabase and gabbro, so widely distributed to the north, and from the Keewatin iron-formations which have suffered so much erosion. Besides these sources, there is the probable source from previous bog deposits which were eroded by the glacier and their contents mixed with the sand. A microscopic examination of the sand showed that iron exists everywhere as a thin coating on the grains, which becomes red and much more conspicuous on heating, by the formation of the red oxide.

However inadequate the sand may appear as the source of the iron, it is the only rock which can furnish it.

TRANSPORTATION OF THE IRON BY WATER.

Regarding the quantity of iron in solution at any time, a few analyses of water collected from the streams and lakes by the writer and analyzed by Mr. S. J. Lloyd, are of interest. On account of the difficulties connected with the transportation, the

quantities of water collected were small, and although the amount of iron present was quite sufficient for accurate determination and silica and manganese were found to be present, it was not possible to determine accurately the percentage of the two latter and carbon dioxide could not be found. There was so much iron in the water that in every case floculent iron hydrate precipitated from apparently clear water, after standing a few days in corked bottles. In one case there was enough of the precipitate to almost cover the bottom of the bottle.

To find, if possible, the relation existing between the proportion of iron carried by the streams and that contained in the lake waters, samples were collected from the most easterly of the Little Bear lakes, near the point where the most iron was precipitated, and from the main creek entering the lake. This creek rises in a large muskeg to the northeast, and the stones in the bed of the stream are red with iron oxide.

Analysis (no. 1) of the water from this stream showed: .061 gramme Fe_2O_3 per liter.

Analysis (no. 2) of the water from the lake showed: .056 gramme Fe_2O_3 per liter and a trace of manganese.

These analyses indicate that a loss of iron occurs almost as soon as the water enters the lake and no. 1 indicates still further that the stream was carrying ferric oxide at the rate of about one eighth of a pound to a ton of water. When one considers that this stream was about three feet wide and four inches deep and flowed at a moderate velocity, an estimate may be made of the amount of iron which would be carried by it in the course of a season. It is stated that in Lac-a-la-Tortue, Quebec, paying quantities of bog ore have been obtained from areas completely exhausted eight or ten years previously,[1] and that the ores are renewed in the lakes of Sweden in twenty-five years.

Three samples were collected from the waters in the vicinity of Hematite Lake and the following analyses obtained. The first analysis (no. 3) was taken from the creek which flows from a small lake and near the outlet of the lake. It yielded .047 gramme Fe_2O_3 per liter. To ascertain the effect produced upon

[1] P. H. Griffin, *Amer. Inst. Min. Eng.*, Vol. 21, 1892–3, p. 974.

the stream by flowing through more than two miles of peat and sand to Hematite Lake, a sample was collected from the stream near the lake and the analysis (no. 4) with .045 gramme Fe_2O_3 per liter, instead of showing an increase, as was anticipated, showed a slight decrease. This decrease might be due to the fact that the sands along its bed had already been thoroughly leached of their iron and the evaporation of water, combined with the oxidation of the iron, produced precipitation instead of solution.

Analysis No. 5 showing .021 gramme Fe_2O_3 per liter was stated by the analyst to be for some reason a little uncertain. However, it represents approximately the proportion of iron carried by the stream draining Hematite Lake, as the sample was collected from the stream near the outlet. Comparing this analysis with that of the water entering the lake, it will be seen that a considerable loss is experienced in the lake water, but about half of the iron which enters the lake passes on with the outflowing stream.

SOLVENTS FOR THE IRON.

It is generally agreed that plants are the chief agents in producing chemical action in the formation of bog iron. Small amounts of iron may be carried as ferrous or ferric sulphates derived by the oxidation of pyrite in the rocks but this quantity must be comparatively small, considering the small amount of sulphur in the deposits, compared with that which is derived by the action of organic acids on the iron-bearing silicates. The action of these acids is well described by Julien[1] in the article already cited and he gives so many examples of the action of these acids, that their importance seems to be fully demonstrated. They are capable of dissolving and freeing sufficient silica to supply the quantity of soluble silica found in bog ores. This quantity varies from almost nothing to over 20 per cent. and in an analysis of concretions already given in this paper the soluble silica amounted to 8.92 per cent.

The organic acids associated with the formation of bog ores

[1] A. A. Julien, *Proc. Amer. Assn. for the Adv. of Sci.*, Vol. 28, 1875, pp. 311–410.

include, among others less common, crenic, apocrenic and humic acids and of these the crenic compounds are probably the most active agents in the solution of minerals. Probably the best illustration of the action of these acids in the formation of ores, is furnished by the chemical experiments of T. Sterry Hunt,[1] by which he showed that a sample of bog iron ore contained 15.01 per cent. of organic acids, crenic and apocrenic.

The action of carbon dioxide is an important factor in the weathering of minerals, but unless it is accompanied by other organic constituents its action is comparatively small. Professor Ossian Aschan[2] claims that organic acids, rich in carbon dioxide, act upon rocks in a chemical manner, and as soon as they have freed some bases, such as potassium, magnesium and iron, certain bacteria are able to begin work and aid in the solution of the minerals by feeding upon the humates developed from these bases. As a result of the action of these bacteria the iron humates are decomposed and finally give up the iron in the form of limonite.

PRECIPITATION OF THE IRON IN THE BOG.

The small amount of ferrous sulphate which is carried into the bog in solution can readily be precipitated by calcium carbonate which is commonly present in solution and the result would be calcium sulphate and ferrous carbonate: $FeSO_4 + CaCO_3 = CaSO_4 + FeCO_3$, if it were not for the oxygen in the air. But as the oxygen of the air is always present at the surface of the bog lakes, the ferrous carbonate is not formed, and instead of it the ferric hydrate results thus: $2FeSO_4 + 2CaCO_3 + 3H_2O + O = 2CaSO_4 + Fe_2O_3.3H_2O + 2CO_2$. Or it is more likely that the ferrous sulphate oxidizes first to ferric sulphate and the following equation represents the reaction: $Fe_2(SO_4)_3 + 3CaCO_3 + 3H_2O = 3CaSO_4 + Fe_2O_3.3H_2O + 3CO_2$. The limonite thus formed collects as a thin film on the surface of the water, to sink later or become collected on objects along the shore. Such a thin film may be seen in almost any

[1] "Geol. of Canada," 1863, pp. 512–13.
[2] *Zeit. für prak. Geol.*, 1907, pp. 56–62.

region where a little stream seeps out of a bank where pyrite is present and it may also be seen where organic material is plentiful and in contact with crystalline rocks. The oxidizing influence is not entirely confined to the surface especially when the water is disturbed by the wind.

The action which takes place when the iron humates, *i. e.*, the iron salts of the organic acids, reach the bog lakes where they become exposed to oxidizing influences, is rather complicated and not fully understood. It is considered, however, that these salts become oxidized and the insoluble limonite results. It is supposed, as already pointed out, that bacteria play some part in the freeing of the iron hydrate from solution, by the breaking up of the humates.

There are certain physical forces which also appear to influence the precipitation of the hydrate. The association of the iron with sandy beaches and the development of the deposits on certain portions of the lake are striking features. The sand grains doubtless serve as nuclei about which crystallization takes place and after some iron has been deposited the force of crystallization causes a further precipitation. This influence of the presence of iron is illustrated in bog iron regions where all the pipes used for the transportation of water become heavily coated with this compound.

The winds which tend to blow from about the same general direction during the summer, when the iron solutions are the most concentrated and likely to produce a maximum precipitation, drive the water toward the northern and eastern sides of the lake. When the waves are continually passed to and fro over the concretions, already formed, precipitation will be aided by chemical affinity and the movement of the water will also bring about more perfect oxidation of the water and thus of the iron humates and cause precipitation of the oxide. These various forces tending to deposit the iron, act in a cumulative manner by increasing precipitation, because of the presence of iron already precipitated, and by building out those spits or points where greatest accumulation occurs, so that the currents along shore tend to converge at certain points and make further deposits.

Examples were seen in the field, of the influence which the direction of the shore currents had in producing deposits, as these commonly occurred where a current drifted along a sandy point.

There is one other factor which may be mentioned, as probably having a small influence on the formation of the concretions. When examining the deposits on the Little Bear lakes, it was found that a person wading out into the water suddenly experienced a very sudden change in the temperature of the water at a short distance from shore, although the wind was blowing at the time and to all appearances the water was pretty well disturbed. The point at which this change occurred was just about the line where the concretions ceased to form on the bottom of the lake and the water became only a little deeper. The cause of this difference in temperature was attributed to the great effect of the reflection of the sun's rays by the sand of the lake bottom, where the water was shallow. The question which arose on making this observation was whether the increased temperature had any influence on evaporation and concentration of solutions and whether the greater amount of light dispersed through the water might have any influence in dehydrating and hardening the limonite.

In the past there has been considerable speculation concerning the cause and process of the hardening and dehydrating of limonite. The observations of W. Spring[1] are interesting in this connection. He states that iron hydroxide spontaneously loses its water if the iron is not combined chemically with some other substance. The yellow ochre color would thus indicate the presence of: Al_2O_3, CaO, MgO, etc.

Wittstein[2] found that if iron hydrate were left for several years under water at ordinary temperatures, it dehydrated and became crystalline. It is also stated that organisms may dehydrate limonite. Spring concludes that iron hydrate is thus not a stable compound and gives up its water when it is not in chemical equilibrium with other oxides.

[1] W. Spring, *Neues Jahrbuch für Mineralogie*, etc., Band 1, 1899, pp. 47–62.
[2] *Vierteljahresschrift für Pharmacie*, 1, p. 275.

THE QUARTZ DIABASES OF NIPISSING DISTRICT, ONTARIO.[1]

W. H. Collins.

Geological investigation and mining operations in Cobalt and the several camps of like character in northern Ontario have demonstrated empirically that the silver-cobalt ore deposits of each are closely connected with certain large intrusive bodies of quartz diabase. In the following pages an attempt is made to discuss the petrology of these bodies, incidentally also to determine the nature of their relations to the ore bodies.

I. THE INTRUSIVE ROCKS.

Geological Relationships.—Scattered patches of diabase occur over 6,000 square miles or more in Nipissing district alone. The geological structure of this area is fairly simple. It is underlain by an uneven erosion basement composed either of granite-gneisses (Laurentian) or by a group of well-foliated, steeply inclined schists (Keewatin). Upon this crystalline floor reposes a much younger, gently folded series of conglomerate, greywacke, slate and quartzite (Huronian). The quartz diabase, which is intrusive into all, appears to have risen through fissures in the basement but, on reaching the overlying sedimentary mantle, found it easier, instead of continuing its upward course, to lift the flat-lying strata and spread laterally either beneath them or along easily separated bedding planes between them. Hence a distinction, though one not without exception, can be drawn between vertical dikes which intersect the crystalline basement and approximately horizontal sills in the Huronian above. The dikes are small bodies varying in width from a few inches to 150 feet but the sills attain thicknesses of 500 feet and horizontal dimensions of twenty miles or more. The intrusion of these large bodies seems to have proceeded tranquilly with little disturbance

[1] By permission of the Director of the Geological Survey of Canada.

of the adjacent strata. Blocks of the latter were torn off and enclosed by the fluid diabase but, as they always retain their angular outlines, there appears to have been no assimilative action. They are, however, altered somewhat in mineralogical composition. Quartzite was rendered hard and glassy; slate and greywacke were changed to adinole. A narrow zone showing the same modification is observable in these rocks wherever they adjoin the sills.

The intrusion is believed to have occurred in pre-Cambrian time though how much later than the Huronian is uncertain. It may bear some relation to widespread post-Keweenawan diabase formations that occur around lake Superior. Subsequent erosion has been severe enough to wear the sedimentary series and its included sills so deeply and irregularly that not only are the latter exposed from top to bottom but much of the crystalline basement, in which the dikes lie, is also visible.

Macroscopic Description.—Owing to the manner of its intrusion the diabase exhibits extreme though inconspicuous variety in composition and texture. The magma was injected as tabular bodies of the utmost diversity in size—from a few inches to hundreds of feet in thickness—which, cooling at very different rates, attained an equally varied perfection of crystallization and mineral segregation. Small dikes contain dense black basalt whose crystalline structure is hardly perceptible. Sill rock varies from medium grained, dark gray diabase to a coarse gabbroid type whose component augite and feldspar crystals may attain lengths of several centimetres. These are the extremes; the larger dikes and the sills furnish varieties intermediate in texture.

Dikes contain diabases alone and differ from point to point only in texture; sills show a further variation in mineralogical composition. Mingled with gabbroid diabase and indistinctly defined from it are occasional masses of equally coarse, dull red rock, often incorrectly referred to in the field as syenite. It is not always easy to discriminate between the two for they occur mingled intimately and in highly variable proportions, though the red one is always subordinate. Sometimes it forms masses several hundred feet across; more commonly the dimensions are

expressible in inches. In one instance a hand specimen contains flecks of it about five millimetres in diameter distributed through ordinary diabase so as to impart a brilliant, mottled coloration. Its distinctive color is produced by an abundance of salmon-colored feldspar; in addition the characteristic augite of diabase is replaced wholly or in part by scales of black mica.

Sill diabase it also cut by dikes of a finely crystalline, light pink rock that, at first sight, does not look unlike quartzite. It consists of grayish pink feldspar and some quartz, dark minerals being virtually absent. These dikes possess sharply defined walls and are nearly always under four feet in width though one at Cobalt is fifty feet wide. The relationship between these aplite dikes as they are called and the diabase is not at first obvious, the two rocks being radically dissimilar. But within the sills, where the diabase is coarse-grained, aplitic material can usually be found mixed with it in irregular, vaguely defined patches after the fashion of the red rock. Comparison of specimens from different localities also shows that aplite is not of constant character. It varies in color from nearly white to deep salmon red according to the color of the feldspar, from finely quartzitic to granitic and it may contain anywhere fram a trace to a large amount of mica. The light pink dike rock proves to be only one aspect, the red "syenite" another, of a single species. They are the end members of a series of types that includes all intermediate gradations between them.

In the form of red rock or other poorly segregated bodies this aplite is contemporaneous with diabase in crystallization. The dikes, however, are undoubtedly later though the time interval was probably short.

Microscopic Description.—Comparative microscopic study of dike and sill rocks confirms the opinion that only two petrological species are present: diabase and an acid differentiate of aplitic nature. The relations of one to the other, however, are intricate and intelligible only by comparing a suite of specimens representing progressive steps in the process of differentiation which, thanks to the unequal masses and cooling velocities of the injected bodies, have been preserved.

The most rapidly solidified material, taken from a dike about a foot wide, consists of minute plagioclase and augite crystals contained in a matrix of dark glass. A dike five feet wide yielded a finely holocrystalline product composed essentially and in about equal parts of irregular augite grains and stout, ophitically penetrating laths of labradorite. Small, angular interstices thus produced are occupied by quartz. Black iron ore and a little pyrite and chalcopyrite occur in irregular grains near augite crystals. The only other accessory constituents are apatite, small rods of which penetrate both augite and plagioclase, and a few flakes of biotite. Plagioclase is twinned after the albite, less frequently also the pericline and carlsbad laws and behaves optically like basic labradorite. Judging by chemical analyses and its abnormally low refringence it probably also contains a certain molecular intermixture of potash feldspar. Augite is faint reddish brown in transmitted light and scarcely pleochroic. A sample mechanically isolated from coarse-grained diabase yielded on analysis the results given under I. of the accompanying table. Its density was 3.34. Biotite, the other ferromagnesian mineral, possesses a strong reddish brown color in basal sections and shows no opening of the optic angle during rotation. The black iron ore, according to the analysis given under II., is a titaniferous magnetite; a gridiron lamellation can be seen in reflected light or in skeletal forms leucoxene results from alteration.

Taking sections in order of increasing coarseness, this description is applicable until medium-grained diabase is reached, when an additional constituent appears—a micrographic intergrowth of quartz and an acid plagioclase near oligoclase in optical behavior. This intergrowth replaces the interstitial quartz of finer textured specimens. Not infrequently it is absent from medium-grained material and, when present, is invariably fine and small in amount; with increasing coarseness of the diabase it becomes more constant and abundant. A large quantity is always present in gabbroid types where it is coarse enough to be distinguished by holding the section to the light. The pattern, of almost conventional regularity in fine-grained diabase, is often imperfect where the containing rock is coarse.

Likewise coincident with increasing coarseness of the diabase is a variation in the proportions of albite and anorthite composing the feldspar. In fine or medium-grained rock this constituent behaves as $Ab_{35}An_{65}$ approximately. As the texture grows coarser it begins to vary; in gabbroid types, where the variation is greatest, it ranges from $Ab_{30}An_{70}$ or even $Ab_{25}An_{75}$ up to $Ab_{65}An_{35}$. The properties of all the other minerals remain constant.

When the plagioclase attains an acidity of $Ab_{65}An_{35}$ it is optically identical with the plagioclase of the intergrowth. Under such circumstances the intergrowth may be especially irregular in pattern and no longer confined to interstitial spaces. Plagioclase crystals having the prismatic habit characteristic of the earlier generation were observed carrying within themselves a loose intergrowth of quartz and, in addition, flakes of mica possessing bright yellow to deep grayish brown pleochroism. In another part of the same section the intergrowth and mica are accompanied by little crystals of titanite.

The aplitic differentiate bears little resemblance to diabase. No ophitic tendency is observable. The texture, though varying considerably, is on the whole much finer. Thin sections are composed essentially of a panidiomorphic mosaic of acid plagioclase, quartz and mica with accessory titanite, apatite, pyrite and chalcopyrite. Specimens differ chiefly in the proportions of their essential constituents. Either quartz or mica may be wholly absent, abundance of one apparently being at the expense of the other. Plagioclase, which always forms over half the mass, ranges from $Ab_{65}An_{35}$ to pure albite as quartz increases. In basic varieties it retains the abnormally low refringence noted in diabase plagioclase. This peculiarity diminishes, however, toward the albite end of the series coincidently with reduction and final disappearance of potassium. Opaque fragments of the plagioclase grade in color from dull red to light pink or gray, probably owing to varying admixture of ferric oxide, since the deeper color is peculiar to specimens rich in mica and closely associated with diabase. Micrographic intergrowths with quartz are not uncommon though a mosaic arrangement is the normal

one. The mica, usually altered to chlorite, differs from that found in diabase in possessing a different and more intense pleochroism: $\mathfrak{a}$ = pale golden yellow, $\mathfrak{b}$, $\mathfrak{c}$ = dark grayish brown. Its optic angle is small. It suggests zinnwaldite in appearance but, as it is always partly decomposed, chemical data wherewith to establish this identity are not available. The accessory constituents are very subordinate in amount and need no special description.

Quantitative Relationships.—It has been seen that both diabase and aplite, particularly the latter, show signs of chemical and mineralogical variation. The feldspar of the former ranges from basic labradorite to andesine, accompanied by perceptible decrease of augite. In the aplites it continues from andesine to pure albite; correspondingly mica diminishes to zero while quartz rises from zero to important proportions. The nature of these variations was more closely investigated by subjecting a series of diabase and aplite specimens to quantitative mineral analysis, Rosiwal's optical method being used. The silica content of each specimen was also determined chemically and the whole plotted upon the accompanying diagram (Pl. VI.), ordinates of which represent percentages of each mineral constituent, abscissæ the silica percentages of corresponding rock specimens.

The aplite series, when so arranged, exhibits a quantitative variability for each constituent that can be expressed by smooth curves. Silica ranges from 50 to 80 per cent. As it rises mica decreases from 33 per cent. to zero, quartz increases from zero to 40 per cent., while plagioclase, after rising from 66 to 70 per cent. falls rapidly to 58 per cent. Titanite remains at about one per cent. throughout. Apatite and the sulphides, though always present, are in too small quantities to be accurately estimated. Aplite may therefore be said to vary in composition in a definite manner and within fixed limits.

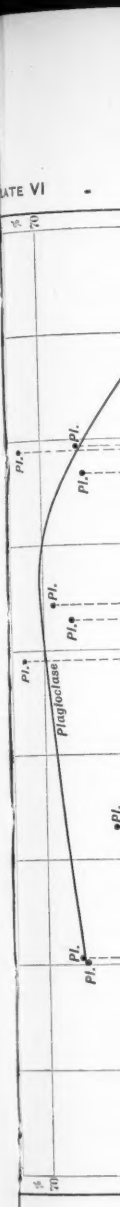
Applying these criteria to all cases, the aplite found in Nipissing district is found to be not always pure. Except in its acid phases it may contain traces of diabase in the form of one or more diabase minerals. As a result there exists between diabase

and aplite a group of hybrids due to intermixture, or rather, imperfect separation of the two species. Magnetite, the most persistent diabase constituent, occurs frequently in basic or even intermediate aplites. The essentially mechanical nature of its presence can be demonstrated by excluding it, recalculating the remaining constituents and applying the results to the diagram. Satisfactory accordance with the properties of pure aplite was obtained in every case treated in this manner.

Augite is sometimes also present at the very base of the aplite series, in the red rock heretofore described, but as both aplite and diabase associations are then fully represented, the hybrid nature of the rock is too obvious to require proof. A mottled diabase described on a preceding page is simply an instance of this kind crude enough to be recognized in the hand specimen.

A first attempt to represent the diabase by curves was less successful; only a number of apparent anomalies were developed. Their silica contents were found to range between 48 and 52 per cent., fully half of them exceeding 50 per cent. and thus overlapping the aplite series. Although plagioclase varied from $Ab_{35}An_{65}$ to $Ab_{65}An_{35}$ it did so in no discoverable relation to the total acidity of the diabase, labradorite inhabiting indifferently the most basic or most acid specimen. For instance, two specimens each containing $Ab_{35}An_{65}$ yielded 48.15 and 52.05 per cent. of silica; another containing $Ab_{65}An_{35}$ yielded only 51.34 per cent. Quartz was found to be in equally uncertain relation to the total silica; though 5 per cent. of the sample that gave 48.15 per cent. silica was quartz another giving 51.85 per cent. silica contained only 2.5 per cent. of quartz.

It was only afterwards that the difference between fine and coarse diabase was noted. No physical distinction had been made in selecting the first materials. However laboratory or even field study implies that differentiation proceeded to very different degrees in rocks of different texture, being noteworthy only in coarse sill rock. Basalt and finely crystalline types are homogeneous and must be considered as undifferentiated mixtures of diabasic and aplitic substances; their silica content—



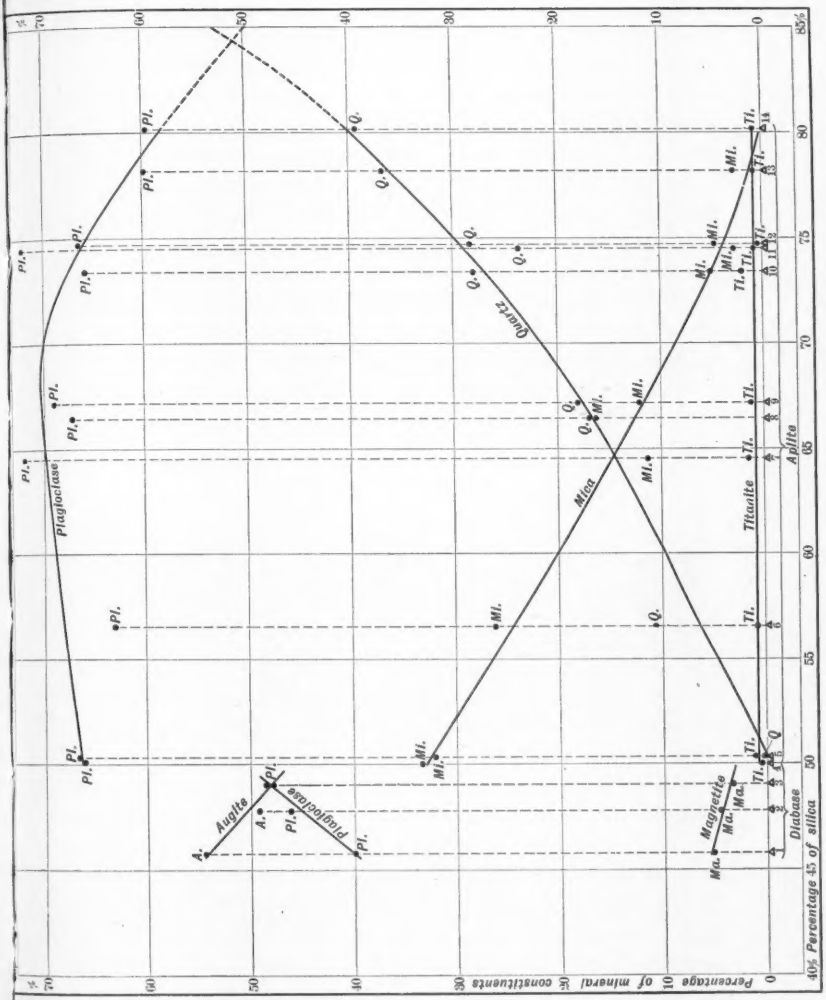


Diagram showing differentiation of diabase magma.

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50.56 per cent. for basalt—exceeds the minimum for aplite. Such being the case, pure diabase, that is, diabase free from aplitic matter, may be expected only in coarsely crystal specimens.

But even these it was discovered do not represent pure diabase. The micrographic intergrowth invariably present in coarse types behaves irregularly. It may be seen from the following table that the quantity of intergrowth is in direct relation to the size of the individual crystals composing the diabase. And, since coarseness of grain is an expression of the rate of cooling it is also proportional to the time of crystallization. The same data indicate no ratio to exist between micrographic intergrowth and total silica. Comparison with the percentages of alkalies present was no more satisfactory. Yet if a chemical relationship obtained these would be controlling factors. Apparently the amount of intergrowth was determined by physical instead of chemical conditions.

	Silica.	Amount of Intergrowth.	Aver. Diam. of Plag Individuals.	Aver. Size of Intergrowth.
1.	50.56 per cent.	None	.2 mm.	
2.	Undet.	Trace	.4 mm.	.014 mm.
3.	Undet.	3.64 per cent.	1.17 mm.	.235 mm.
4.	51.85 per cent.	4.90 per cent.	1.25 mm.	.212 mm.
5.	48.15 per cent.	8.48 per cent.	2.75 mm.	.320 mm.
6.	50.81 per cent.	11.44 per cent.	3.37 mm.	.615 mm.
7.	52.05 per cent.	12.31 per cent.	3.54 mm.	.884 mm.

Its identity is suggested by certain similarities. It is an acid segregation from diabase. It contains two of the three essential components of aplite. Sometimes it associates with mica and titanite, becoming then fully identical with that species, which is itself an acid segregation from diabase magma. In short, its mineralogical character, associations and manner of expulsion imply it to be an initial and incipient form of aplite.

Pure diabase is obtainable, theoretically, by eliminating from an ordinary gabbroid specimen the micrographic intergrowth present and recalculating the residual minerals to unity. This was done with a limited supply of suitable material at disposal. The data derived, while too scanty to be absolutely reliable, point to only one conclusion. When so reconstructed each specimen

consists of plagioclase, augite and magnetite besides accessory apatite, pyrite and chalcopyrite; in other words, it contains the same mineral assemblage as ordinary quartzless gabbro or diabase. The silica content varies from 46 to 50 per cent. The essential constituents are representible in respect to quantity in the same diagrammatic manner as the essential constituents of aplite, augite diminishing from 55 to 48 per cent., plagioclase increasing from 40 to 48 per cent. and magnetite sinking from 5 to 3 per cent. as the total silica rises. Simultaneously with this change plagioclase graduates from $Ab_{35}An_{65}$ to $Ab_{65}An_{35}$, its discordant relations to the total silica disappearing. As in the case of the aplite series, we have variation of definite character within fixed limits.

At the acid end of the diabase series mica begins to replace augite, titanite takes the place of titaniferous magnetite and aplite is evolved. Plagioclase alone remains unchanged in composition, so far as may be inferred from its optical character: its quantity, however, increases from 48 to 66 per cent.

	I.	II.
SiO_2	48.00	9.34
Al_2O_3	4.31	2.77
Fe_2O_3	3.06	30.91
FeO.	17.34	31.16
TiO_2	0.91	17.40
CaO	14.84	5.40
MgO	9.82	0.90
K_2O	0.15	....
Na_2O	0.91	....
$-H_2O$	0.07	0.08
$+H_2O$	1.00	1.29
	100.41	99.75

I. Analysis of augite separated from diabase samples, by M. F. Connor.
II. Analysis of iron ore separated from diabase sample, by M. F. Connor.

II. INTRODUCTION OF CALCITE.

In pure form aplite consists essentially of plagioclase, mica, quartz and, though in small quantities, titanite. A majority of specimens contain calcite also. In fact this mineral is seldom entirely absent. The amount present is ordinarily small but

occasionally it attains one fourth of the rock mass, less frequently one half or over, in which case the rock resembles the filling from a calcite vein containing crystals of plagioclase. Twice in the field aplite dikes were observed to pass by easy gradations into calcite veins. In such cases the feldspar individuals grow much larger than in ordinary aplite; a specimen selected from one of these transitional dikes consists of albite crystals half an inch long embedded in calcite.

The calcite possesses no crystal form; it occupies irregular spaces between the other minerals. Sometimes a small share is secondary, resulting from alteration of mica but most of it bears all indications of having crystallized at the same time as the other constituents.

Yet it can scarcely be native to the aplitic substance. The dominant tendency of differentiation in diabase and aplite alike is toward increase of silica and soda with diminution of all other components. Lime never exceeds 12 per cent. in diabase and virtually disappears toward the acid end of the aplite series. A number of calcite bearing specimens were analyzed in the manner elsewhere employed in this investigation and the results applied to the diagram with intent to introduce a calcite curve. The attempt was entirely unsuccessful. The same results were then recalculated, after subtracting calcite, and again plotted, this time with satisfactory results. Several chemical analyses[1] of calcites bearing aplites were also utilized by expressing their components in the form of aplite minerals and treating as before with like result. It was concluded therefore that calcite is not a member of the aplite mineral association in the same chemical sense as plagioclase quartz or mica; also that its presence does not materially influence the quantitative relations of these constituents. It acts like a foreign substance.

If so it must have been obtained from some external source by the aplitic fluid. There are four alternatives: the already solid diabase, Huronian sediments, Laurentian granites or Keewatin schists. Probably it was derived from the three last

[1] N. L. Bowen, *Canadian Mining Journal*, April 15, 1909.

named groups, but in largest amount from the Keewatin. The schists comprising this group carry an abundance of secondary calcite. Diabase is an unpromising source. Its comparatively small lime content is firmly bound up in the form of silicates. Little or no decomposition such as would be necessary to release it is perceptible in proximity to aplite bodies. It is also noteworthy that the diabase contains no calcite, either primary as in aplites or secondary from alteration of plagioclase or augite.

III. VEIN DEPOSITS.

Diabase sills and the older rocks for some hundreds of feet above and below are traversed by mineralized veins. These, although usually designated calcite veins are occupied by a mixed gangue of quartz and calcite. Quartz grows from the walls, its crystals terminating freely in a central, calcite-filled cavity. The proportions of the two minerals are highly variable; sometimes the entire fissure is filled with quartz but more commonly calcite occupies half or more of the available space. Barite, rarely also celestite, may accompany or replace calcite. The primary ores are sulphides, arsenides, sulph-arsenides and sulph-antimonides of silver, cobalt nickel and copper with native silver and bismuth. Chalcopyrite is probably the most abundant individual mineral though this fact is obscured by its inferior commercial value.

The veins accompany diabase sills too constantly to allow of doubt regarding their mutual relationship. Certain mineralogical relations corroborate this opinion. Thus, differentiation of the intrusive rock proceeds from comparatively basic diabase toward an aplite whose acid phase is composed of quartz and albite only. The curves of these two minerals indicates rapid diminution of albite and correspondingly rapid increase of quartz. The ultimate product of this process if allowed to continue would be nearly pure silica, that is, a quartz vein. A complete gradation from aplite to quartz veins has not been observed and possibly does not exist for the same reason that a perfect transition from diabase to aplite does not obtain: an abrupt mineralogical rearrange-

ment separates them. It is not improbable that, with greater dilution, lower temperature and in the presence of much magmatic water albite would go over into some other form.

The calcite which accompanies quartz in the veins is no doubt derived in the same way as by the aplite, and its greater abundance is perhaps due to the greater fluidity and consequent greater power of solution of the vein-filling solution. It is significant that barite and celestite have been found only in veins where the associated diabase overlies Laurentian rocks, which contain occasional veins of these minerals. Analyses of diabase fail to detect either strontium or barium.

The ores are less easy to trace. However, chalcopyrite and pyrite, both conspicuous vein minerals, occur throughout the diabase and aplite series. Chalcopyrite accompanies aplite dikes not only in primary disseminated grains but in much larger quantities as fissure fillings. Copper was sought by chemical analysis in a basaltic sample of diabase, also in a sample of augite isolated from coarse grained diabase and found in small quantities in each. Cobalt and nickel, however, could not be detected.

IV. CONCLUSIONS.

I. The diabasic magma which filled various dikes and sills in Nipissing district, Ontario, behaves as a homogeneous mixture or, more probably, a mutual solution of two chemically and mineralogically definite rock species designated diabase and aplite. The former consists of three essential minerals, plagioclase, augite and titaniferous magnetite whose relative proportions vary mutually in the following manner:

	Per Cent.
Plagioclase (bytownite to andesine)	40–48
Augite	55–48
Magnetite	5– 3
Corresponding silica variation	46–50

Aplite consists likewise of:

	Per Cent.
Plagioclase (andesine to albite)	66–70–58
Mica	33– 0
Quartz	0–40
Titanite	1 throughout
Corresponding silica variation	50–80

After intrusion, when a sufficiently low temperature was reached the two species crystallized, diabase somewhat in advance of aplite. Simultaneously they commenced to segregate from each other. Owing however to the exceedingly unlike dimensions of the various injected bodies of magma, and consequent differential rate of cooling, also to imperfect fluidity, segregation was accomplished in highly different degrees. A portion of the aplite did escape, forming dikes and irregular masses in the diabase but much of it was imprisoned within the latter, chiefly in the form of a micrographic intergrowth of quartz and acid plagioclase. This gave rise to a confusing variety of hybrid rock forms, of which the commonest is quartz diabase.

Diabase is greatly in excess of aplite. Upon reaching its most acid state it goes over into aplite by substitution of mica for augite and titanite for titaniferous magnetite.

II. The aplitic fluid abstracted calcite from adjacent rocks, chiefly Keewatin schists. This crystallized out after the manner of a primary constituent but does not exhibit a stoichiometric relationship to true members of the aplitic mineral association.

III. The extreme residual differentiation product formed quartz-calcite veins carrying various ores of copper, silver, cobalt and nickel. Quartz and probably chalcopyrite also were derived from the original magma but the calcite and small amounts of barite and celestite that accompany it infrequently were extracted from older neighboring rocks as in the case of the aplites. No positive evidence regarding the origin of the silver, cobalt and nickel compounds was obtained.

STRATIGRAPHIC RELATIONS OF THE LIVINGSTON FORMATION OF MONTANA.[1]

PART I.

R. W. STONE AND W. R. CALVERT.

INTRODUCTION.

Livingston, Mont., is the type locality of a widespread formation concerning whose age and stratigraphic relations there has been much discussion. This is known as the Livingston formation. It is made up largely of andesitic material, and has hitherto been regarded as marking a unique episode in American geologic history, since its deposition was supposed to have followed a period of orogenic movement and to record a period of intense volcanic activity and rapid deposition of material derived from this activity in delta-like deposits near the shore. It was supposed also to overlie unconformably a coal-bearing formation which has been called "Laramie," hence the Livingston was believed to be of post-Laramie age.

It is the purpose of this paper to show: (1) That the coal-bearing formation of the Livingston section is not Laramie, but is Eagle or at least lower Montana in age; (2) that the andesitic beds above, known as the Livingston formation, are not separated from the underlying formation by an unconformity anywhere within the area discussed, and (3) that their peculiar lithologic character is not a criterion of specific age but is a shore phase of many formations ranging from Colorado to Ft. Union, inclusive.

The data upon which the above conclusions rest are the result of field study during three consecutive years. In the summer of 1907 R. W. Stone investigated an area adjacent to and mainly on the north side of the Crazy Mountains, for the purpose of ascertaining the possible coal resources, beginning near Shawmut

[1] Published with the permission of the Director of the U. S. Geological Survey.

on Musselshell River and ending near Clydepark on Shields River. The following year W. R. Calvert in pursuance of similar investigations mapped an area lying between Yellowstone River and the mountains to the south, beginning at Red Lodge and extending westward nearly to Bozeman, thence north along the east flank of the Bridger Range nearly to Stone's area of the year previous. A small area at Electric, adjacent to Yellowstone National Park, was also examined. As a result of these stratigraphic studies interpretations radically different from those previously held were given to the geologic relations of the Livingston formation, and in the summer of 1909 M. R. Campbell, F. H. Knowlton, T. W. Stanton and the writers made a ten days trip from Livingston north and around the Crazy Mountains to revisit certain critical localities and to verify and extend if possible the observations of Stone and Calvert in the years 1907 and 1908.

HISTORICAL REVIEW.

The Livingston formation was first recognized by Weed[1] in 1890, while studying the geology of the Livingston region in continuation of the work of the Yellowstone Park survey. Prior to that time the general region was visited and described by various geologists, the earliest so far as the writers are aware, being those of the Hayden Survey in 1871–72. In Hayden's report[2] mention is made of the dark-colored rocks overlying the coal measures, but they were considered as largely metamorphic in character. Later work by Lindgren[3] for the Northern Transcontinental Survey established the volcanic nature of the material composing the Livingston formation and it was considered by him as belonging to the "Laramie." In fact, even at the time of Weed's investigation the entire section from the base of the coal measures to and including the highest sedimentaries found in the Crazy Mountains was placed in the "Laramie." Weed, however, reached the conclusion that the term "Laramie" should be restricted to the lower thousand feet of beds, and that

[1] Weed, W. H., Bull. U. S. Geol. Survey, No. 105, 1893.
[2] F. V. Hayden, "Geol. Survey of Terr.," 1871–72.
[3] W. Lindgren, Tenth Census U. S., Vol XV., p. 725.

these are overlain unconformably by 5,000 feet of lithologically and paleontologically dissimilar rocks comprising a new formation which he named the Livingston, while the still higher beds within or immediately adjacent to the Crazy Mountains were considered to be representative of still another geological age, namely, the Fort Union. He closely investigated the stratigrapic relations of these formations and states clearly that throughout the area studied by him there is no evidence of unconformity between the coal-bearing "Laramie" and the underlying shale, but that such an unconformity exists between these beds and the overlying Livingston formation.

Several lines of stratigraphic evidence are presented by Weed in proof of unconformity at the top of the coal measures. The main point is that Peale discovered a strongly marked break at this horizon near Sphinx Mountain in the Madison Range south of Bozeman. Weed admits that the evidence for unconformity in the Livingston region is not so definite and based his argument upon three factors. It was his belief that near the eastern border of the Livingston quadrangle the middle member of the Livingston formation (volcanic agglomerates) rests unconformably on lower rocks down to the Colorado. Elsewhere, according to Weed, there is an abrupt change in lithology at the top of the coal measures, which was also interpreted as meaning unconformity. The most satisfactory evidence, however, seemed to be the character of a coarse conglomerate near the head of Brackett Creek, as it contains pebbles from rocks low down in the geologic column. Since by Weed's statement this conglomerate is in the upper part of the Livingston it is difficult to conceive how this fact can be used as an argument in favor of an unconformity 5,000 feet lower in the series. All these points, however, will be discussed more fully later in this paper.

Weed also mapped the outcrop of his "Laramie" formation from east of Livingston north along the Bridger Range and around the Crazy Mountains to Lebo Creek without questioning in any way either its identity or persistency. He seems to have recognized that at all points the rocks of this formation are essentially alike—heavy beds of sandstone with intercalated beds

of shale and coal, and differing only in their aggregate thickness.

Owing to the assumption of a great unconformity between the "Laramie" and the Livingston formation the assertion has been made that the strata of the Livingston region record a sequence of events similar to that of the Denver Basin in Colorado described by Eldridge[1] and Cross.[2] The observations to be given in this paper of the stratigraphic relations of the Livingston formation therefore differ materially from previous interpretation of the geologic sequence involved and may possibly have an important bearing on the meaning of the Denver and Arapahoe formations in the Denver Basin.

In addition to the areal mapping of the Livingston formation by Peale in the Three Forks quadrangle, by Weed in the Livingston and Little Belt Mountains quadrangles, and stratigraphic studies by the geologists of the Hayden and Northern Transcontinental surveys, the work of several others deserves mention. F. H. Knowlton and A. C. Peale have made numerous field trips to the region and have studied the interesting flora associated with the Livingston formation; T. W. Stanton has also studied the greater part of the region in considerable detail, and to him is due the credit of having first suggested that the stratigraphy had not been interpreted correctly; while the work of Stone and Calvert was done under the general supervision of M. R. Campbell whose interest and aid in solving the field problems involved has been unfailing.

RED LODGE—NYE AREA.

As stated in the introductory portion of this paper, the Livingston type locality and adjacent areas were studied by Calvert in 1908, while engaged in classifying coal lands between Red Lodge and Bozeman. In this work he was assisted in the field by F. H. Kay and E. F. Schramm to whom he is indebted for

[1] "On some Stratigraphic and Structural Features of the Country about Denver," *Proceedings Colo. Scientific Soc.*, 1888–9, pp. 86–118.

[2] "The Denver Tertiary Formation," *Proceedings Colo. Scientific Soc.*, 1889–90, pp. 119–133. Also "Geology of the Denver Basin in Colorado," U. S. Geol. Survey, Mon. XXVII., 1896.

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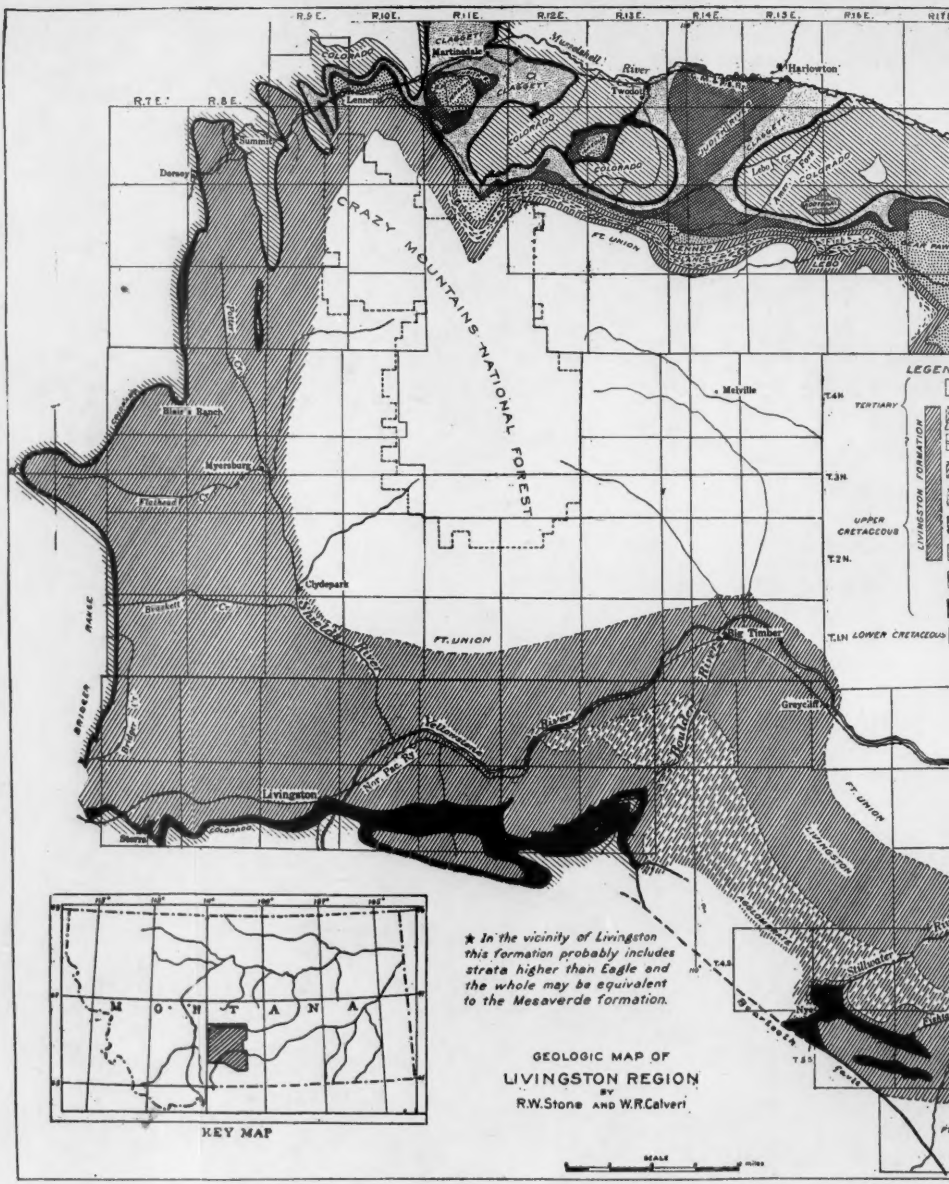
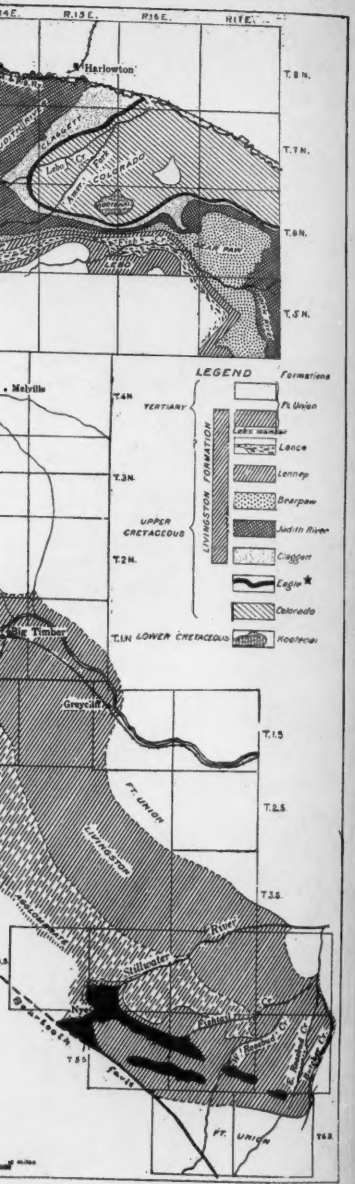

R.9 E.
R.10 E.
R.11 E.
R.12 E.
R.13 E.
R.14 E.
R.15 E.
R.16 E.
R.7 E.
R.8 E.
CRAZY MOUNTAINS NATIONAL FOREST
Harlowton
Melville
Livingston
Clyde park
Timber
Greycliff
Big Timber
Sheep Mt.
Sweet Grass Hills
Bozeman
Boulder
Logan
Three Forks
Summit
Dorsey
Black's Ferry
Myersburg
Flathead Cr.
Bridger Range
Elbow Cr.
Shields River
Yellowstone River
Boulder River
Mission Cr.
Sheep Creek
Trail Creek
Sixteen Mile Creek
Twenty Mile Creek
Dry Fork
Antelope Cr.
Sixteen Mile Cr.
Fourteen Mile Cr.
Twelve Mile Cr.
Ten Mile Cr.
Nine Mile Cr.
Eight Mile Cr.
Six Mile Cr.
Five Mile Cr.
Four Mile Cr.
Three Mile Cr.
Two Mile Cr.
One Mile Cr.
Mundell Cr.
Martindale
Lennep
Summit
Dorsey
Flathead
Bozeman
Boulder
Logan
Three Forks
Livingston
Big Timber
Greycliff
Melville
Harlowton
Clyde park
Sheep Mt.
Sweet Grass Hills


R.14E.
R.15E.
R.16E.
R.17E.
Harlowton
T.8N.
T.7N.
T.6N.
T.5N.
Melville
T.4N
T.3N.
T.2N.
T.1N
Big Timber
T.1S.
T.2S.
T.3S.
T.5S
Ft. Union
Livingston
Stillwater
Yellowstone
Boulder
Pompeys Pillar
LEGEND
Formations
TERTIARY
Ft. Union
Lake beds
Lance
Lennep
Bearpaw
UPPER CRETACEOUS
Judith River
Claggett
Eagle
Colorado
LOWER CRETACEOUS
Kootenai
LIVINGSTON FORMATION

field notes and for aid in mapping the areal geology of the district covered. Work was begun at Red Lodge, a town located in T. 7 S., R. 20 E., and consequently not within the area shown on the map.

Coal-bearing Fort Union rocks constitute the surface formation near Red Lodge and these dip southward until terminated by a profound fault along the base of the Beartooth Mountains. This fault trends northwest-southeast and enters the area shown on the map in T. 6 S., R. 17 E. In the northeast part of T. 6 S., R. 18 E., rocks underlying the Fort Union[1] were first noted in an anticline approximately paralleling the mountain front. The lowest rock exposed is a soft, light-colored sandstone merging upward into chocolate-colored grit and sandy shale, the grit and shale being essentially andesitic in character. A section measured in this locality is as follows:

	Feet.
Brownish platy sandstone and sand shale	1,500 est.[2]
Sandstone, platy, brownish gray, with layers of chocolate-colored concretions up to one foot in diameter	99
Partly concealed, lower 100 feet is yellowish brown, platy sandstone and yellowish sandy shale	287
Sandstone, very irregular in lithology and bedding, coarse-grained to pebbly	55
Brown sandstone and sandy shale	120
Partly concealed; where exposed consists of brown sandy shale and thin brown sandstone	880
Sandstone, gray or brown with intercalated yellowish shale; texture and bedding variable, chiefly fine-grained and tuffaceous, with plant fragments	214
Shale and thin platy sandstone, brownish gray, compact and fine-grained	11
Sandstone, thin-bedded, coarse-grained	39
Shale, gray and yellow, with thin sandstone and lignitic bands	28
Sandstone, white, massive, the grains being waterworn quartz; base not exposed	50

[1] It should be stated that the Fort Union as mentioned in this connection may include the "Ceratops beds" at its base. The Ceratops horizon was not noted, however, and the entire mass at Red Lodge, 8,000 feet or more thick, was mapped in the field as Fort Union.

[2] Owing to low and somewhat variable dips no accurate measurement of this member was possible.

Having in mind the geologic section as described in the Livingston folio, there was no hesitancy in the field in correlating all but the lowermost member of this section with the Livingston formation and the basal sandstone itself with the "Laramie," a classification later approved by Knowlton on the evidence of fossil plants, found in the white sandstone and in the overlying andesitic beds through a stratigraphic range of 1,500 feet.

It will be recalled that in the Livingston folio the Livingston formation is described as composed of andesitic rocks, which rest unconformably on white quartzitic and coal-bearing sandstones assigned to the "Laramie," and these in turn overlie 3,000 feet or more of shale and sandstone said to constitute the Colorado and Montana groups. Westward from the locality where the section just quoted was measured, careful study was made of the stratigraphic relations of the various formations. With the possible exception of one restricted area, the base of the coal-bearing sandstone is not exposed east of Stillwater River. The locality in question is on the east bank of the Stillwater, where about 100 feet of dark shales are shown. These are marine in appearance, but apparently lacking in fossils, and there is some doubt regarding their exact relation to the coal measures. The anticline to which reference has been made gave excellent opportunity to study relations at the top of the coal measures however. It was noted that the contact between "Laramie" and Livingston was a difficult one to define, depending as was supposed on the distinction of quartzitic material in the former and of andesitic material in the latter, for the beds were found to be transitional through a zone varying from 50 to 100 feet. In this district, therefore, there is every indication of continuous deposition and this relation between the two formations remains constant.

Near the west side of T. 5 S., R. 18 E., the agglomerate member of the Livingston, as described by Weed, first appears as a thin intercalated wedge, which thickens rapidly westward to 2,000 feet or more in the hilly country near Stillwater River. This agglomerate is composed almost entirely of andesitic pebbles and boulders, usually not waterworn, and arguing therefore a nearby

source. The beds beneath, termed leafy beds by Weed on account of abundant fossil leaves found therein, are about 600 feet thick, between the Stillwater and the locality where the agglomerate first appears. Weed states that local unconformity occurs between the leaf beds and the agglomerate on Boulder River, and an unconformity at this horizon was noted by Calvert on West Rosebud Creek. The unconformity is slightly angular in character, the agglomerate lying horizontally on leaf beds having a maximum dip of about 5°. The upper limit of the agglomerate member did not fall within the area mapped in detail by Calvert in 1908, except in T. 5 S., Rs. 17 and 18 E., and the contact line, as shown on the map, is based on several points determined in the course of reconnaissance trips. The contact line between the Livingston and the Fort Union was likewise not determined carefully north of T. 5 S., R. 18 E., except at the crossings of Rosebud Creek, Stillwater River and the Yellowstone. In the vicinity of Big Timber, its location was not accurately determined, but is believed to be approximately correct.

In regard to the relation between the Livingston and Fort Union formations in the southeastern part of the area shown on the map, no definite statements can be made. As a rule exposures along the contact are not good, and many minor flexures add to the difficulty in the field. There seems to be no evidence of an unconformity, however, and where exposed the beds of the lower formation pass by gradual transition into the upper. The lowest plants found in the Fort Union were from a horizon 300 feet above the brown rocks of the Livingston formation and contained, according to Knowlton, the following: *Platanus raynoldsi* Newb., *Aralia natala* Newb. and *Populus* sp.

DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, Sheffield Scientific School of Yale University, New Haven, Conn. The full name of the author should be attached to all communications.

CRITERIA OF DOWNWARD SULPHIDE ENRICHMENT.

DISCUSSION OF PAPER BY F. L. RANSOME.

Sir:—Formulation of critical criteria for the recognition of any natural phenomena carries with it, by implication at least, the assumption that there exists a certain complexity of attendant conditions. This at once gives rise on the one hand to a question as to the verity of such implication, and, on the other hand, to a query as to whether only a given immature stage in the knowledge of the subject has been reached. The general theme often may be viewed more broadly than previously had been done.

We now all recognize that it was a great forward step in our knowledge of ore-genesis when Posepny so clearly differentiated the vadose zone from the profound zone; but the main criterion upon which he relied to distinguish in the field the dividing line between ores occurring in the two was far from being valid. Yet in his assumption that mere presence of sulphide ores was *prima facie* evidence of the direct origin of the materials from the depths he was warmly supported by Le Conte and others.

When a few years later it was found that at the base of the vadose zone, at groundwater-level, oxidized ore-material in solution undergoes marked reduction upon coming in contact with the primary sulphides and that a distinct zone of "enriched"

sulphides were produced another and not less notable advance in the knowledge of ore-genesis was thought to be made. The fact that in some localities secondary enrichment of ore-veins is the result of the reactions of vadose mineral-bearing waters upon unaltered pyrite, has indeed a very great practical bearing upon exploitation; but it is not perhaps the only or even the most important of all reactions.

In this connection the fact should not be overlooked that another aspect of secondary enrichment of mineral veins at groundwater-level was definitely, fully and clearly explained as early as 1873 by T. Sterry Hunt, who ascribed the formation of the bonanza zone to the presence of organic matter. The real significance of Hunt's suggestion has been obscured by the fact that subsequent writers on ore deposits have commonly classed ores of this kind as a distinct type. To an indeterminate extent organic reduction probably always operates in conjunction with reduction by pyrite. What may prove to be the most important of all factors in secondary enrichment is the production of the sulphides by reduction through means of the natural silicates.

Secondary sulphide enrichment at groundwater-level thus appears to be a universal and not merely a local phenomenon. The question naturally arises whether we should not regard the vadose zone much as we do the regolith, with a bonanza zone at the bottom, in some places well developed, in others but feebly represented.

Since the appearance of the able papers of Weed and of Emmons on the secondary enrichment of the ore deposits of Butte it has become quite the custom in applying their principles to restrict the action to those ore deposits which have direct connection with low-grade veins primarily formed and manifestly filled from the depths. That identically the same principles, chemical conditions, and geologic structures are involved in cases where no lodes previously existed is abundantly demonstrated by such deposits as those of lead and zinc in the Ozarks, by the silver deposits of Lake Valley, New Mexico, and numerous other localities. These facts suggest that so-called secondary enrichment at groundwater-level is a general rather than a special process.

Entirely too much stress seems to be placed upon the importance of the rôle of pyrite in mineral veins as a producer of secondary enrichment. Important as it may be there should not be excluded all other factors involved in the sulphidation of oxidized ore materials. At a matter of fact the phenomenon of secondary enrichment by means of pyrite is, as already intimated, only a single phase of many, and is perhaps not by any means the most vigorous. In most reported cases the alleged reducing action of the pyrite appears to have taken place in conjunction with other deoxidizing influences. It would be of great scientific interest, even if not of so much practical import, to have evaluated in a few particular cases the relative activities of these several factors.

The so-called zone of secondary sulphide enrichment may be viewed from another angle. Groundwater-level is commonly assumed to be a definite plane in the vadose zone separating oxide ores from ore sulphides. Generally speaking this is probably true. However, in mine waters carrying more than a single metallic salt in solution it is also probable that the actual hypsometric level at which sulphidation takes place is slightly different for different metals. This zonal disposition of the various metallic minerals is of course best observed in the instance of vertical veins, but this is merely a special case. The modification which ore materials undergo below the bonanza zone is also in all likelihood very considerable and varied. As yet this appears to be almost an untouched field.

In such cases as those just mentioned it is invariably assumed that the materials for the enrichment come entirely from the higher parts of the vein itself. This does not seem to be borne out by many observed facts. The bulk of the ore materials for local enrichment actually appears to be derived mainly from the general vadose circulation. Although groundwater-level may be regarded as a plane extending throughout the globe, it only locally permits to notable extent the sulphidation of oxidized ore materials to take place. Localization is dependent largely, if not entirely, upon geologic structure and particularly certain geologic

conditions. Conditions of impounded waters appear to be oftenest essential to accumulation of ore-bodies.

Since trunk-channels of subterranean circulation only become lines of ore-deposition when they become clogged or dammed, producing lakelets as it were, they are usually carrying off ore materials. As recently set forth this procedure is clearly demonstrated in the case of the lead and zinc deposits of the Ozark region. The geologic structure most commonly conducive of the necessary conditions of underground empoundment are gentle foldings of strata, faults, warpings, damming of subterranean passages, and inequalities of unconformities. To a preëminent degree the preëxisting mineral veins also offer lines where local empoundment may take place, because usually rock-decay here goes on more rapidly and deeper in the veins than in the country-rock inclosing them. Were such mineral veins open lower down permitting the free movement of phreatic waters, as in the case of trunk-channels, it is not at all probable that any notable accumulation of ore-bodies, or enrichment, would ever take place at groundwater-level, no matter how abundant pyrite might be.

There is still another factor which must receive serious consideration. If we are to accept the planetesimal hypothesis of the origin of our earth the augmentation of metallic materials from space must be both constant and appreciable. It must find some satisfactory disposition. On this theory the original and often the immediate source of the ores cannot be in its nature so largely magmatic as it is vadose. We can easily imagine in what manner metallic substances of meteoritic origin may become incorporated with ore-materials generally. After reaching the surface of the earth, both cosmic dust and the larger meteorites must mingle with the soil, more or less quickly oxidize, and enter, by means of the circulating groundwaters or otherwise, the deep-seated zone, in the same way that any of the heavier mineral particles liberated from the surface rocks through decomposition are supposed to do. The processes involved are essentially the same as for the changes and movements of rock-forming ore-materials. The distinction to be made is that, instead of the ore-materials being derived from the breaking-down of the rocks of the litho-

sphere, a very large proportion is regarded as coming from extra-terrestrial sources. Although there is probably no such uninterrupted sea of groundwater as that postulated by Van Hise, there is yet reason for believing that surface-water readily penetrates to the deep region, even to the zone of rock-flowage. The lithosphere thus represents merely the flotsam and jetsam of the globe, through which the heavier materials may migrate, generally inward as individual particles, but occasionally or spasmodically outward in connection with volcanic flows.

As migration of ore-materials into the interior of the earth goes on temporary ore-bodies are often localized, in the vadose zone chiefly. How much of these materials are of recent extra-terrestrial origin and what proportion is a product of rock-decay, is at present difficult to estimate. The meteoritic contribution has received as yet insufficient attention. That it may be much more important than has been suspected hitherto, is clearly shown by recent observations in desert-regions. That this is the main source of vadose ore-materials now seems not unlikely. It is probable that most of the diffused metallic content of the sedimentary rocks is in reality immediately derived from meteoritic sources; for its derivation from the country-rock of mining districts, especially in tracts far removed from volcanic activity, has never had a very satisfactory explanation.

Viewed broadly the process of downward sulphide enrichment is not necessarily always ore enrichment at all, in the strict sense of the word. It is really a method of original ore-genesis. It is a general geologic process, intimately dependent upon secular wasting of land-surfaces, manifesting itself in those regions of the globe in which erosion is going on most rapidly, and making its effects most conspicuous locally where geologic structures are especially favorable. Low-grade fissure veins are common locations for sulphide enrichment not so much perhaps because of pyritic content as on account of their furnishing particularly favorable geologic conditions. This is shown by the fact that ore-bodies form in the same way in places where no mineral veins previously existed; the entire ore-body being in fact a "sulphide enrichment."

By imposing definite vadose limitations and certain other restrictions as is now able to be clearly and logically done, downward sulphide enrichment becomes merely a special phase of strict lateral-secretion, as Sandberger so strongly urged but so vaguely understood. The main results of the various recent attempts to formulate criteria for distinguishing the effects of this process from those of ascending mineral waters have been thus in reality to support and emphasize strongly the verity of the Sandberger conception. The desideratum, therefore, is not so much criteria for the determination of downward sulphide enrichment after working mines are already fully opened up, as it is for the establishment of guiding principles that before excavation has proceeded very far will aid in accurately predicting the encountering of such enrichments. The former is really of small value practically because the process is probably universal in action. The formulation of criteria that will lead to the discovery of enrichments would be of priceless value.

As they are stated there appears to enter into the criteria rather too much of the purely theoretical element for the average mining man to successfully use. Regarding the factor of topography, for instance, in the region from which illustration is drawn, were the accepted notion of the manner in which the surface relief was formed measured by such a criterion antithetical conclusions might easily result with change of viewpoint. Nevertheless by his arrangement of the criteria which he regards of most importance in so-called downward enrichment Mr. Ransome has rendered to his fellow workers a distinct service and one that cannot be soon forgotten.

In fine, the principle of downward sulphide enrichment of mineral veins seems to take on the extraordinary importance ascribed to it mainly because something of the kind must be recognized in order to explain some of the most obscure phenomena concerning ore deposits when their derivation is assumed to be entirely from the depths of the earth through means of volcanic activities. The problem is vastly simplified by recognizing at the outset the strictly lateral-secretion character of ore deposits gen-

erally of the vadose zone, which indeed probably actually furnishes the major part of all the metals mined in the world to-day.

CHARLES R. KEYES.

THE ORIGIN OF PETROLEUM.

DISCUSSION OF PAPER BY LEONARD V. DALTON.

Prof. Dr. *Rudolf Zuber* hat auf pg. 194 dieser Zeitschrift sich darauf berufen, dass er zuerst darauf hinwies, dass das Erdoel durch Fermentation der *Cellulose* entstanden sei, und dass *Engler* und ich unsere Theorie vom animalischen Ursprung des Erdoels "vegetablized" haetten, worin er eine Annaeherung an seine Hypothese zu erblichen scheint.

Dies ist jedoch ein arger Irrtum. Wir stehen nach wie vor auf dem Standpunkt, den auch *L. V. Dalton* teilt, dass das Erdoel vorwiegend animalischen Ursprungs sei; da wir jedoch fanden, dass in der niederen Pflanzenwelt auch fett- und stickstoffreiche Arten vorkommen, welche sich also der chemischen Konstitution der Tiere sehr naehern, so haben wir konseguenter Weise es fuer moeglich gehalten, dass auch diese Mikroflora zur Oelbildung beigetragen haben kann.

Die Entstehung des Erdoels aus Cellulose jedoch haben wie—*Engler* und ich—aus teiftigen Gruenden ganz entschieden abgelehnt. Dies wurde bereits in meinem Buche "Das Erdoel und seine Verwandten (2. Auflage 1906, auf pg. 158) und in meiner "Geologie des Erdoels, etc. (1909), auf pg. 83, 93 und 105 eingehend bewiesen, weshalb ich mich mit diesem Hinweisen bewegen kann.

HANS HOEFER.

LEOBEN, 6. Mai 1910.

VULCANISM AND DIFFERENTIAL PRESSURE IN ORE DEPOSITION.

Sir:—Referring to the August, 1909, number of ECONOMIC GEOLOGY and more particularly to the articles by Waldemar Lindgren, Victor Hartog and G. A. Denney, I am much impressed with the evident fact that geologists refer to cause and

forces which they fail to fully define, for the simple reason, as Mr. Lindgren points out in his opening paragraph, that "we are gradually coming to the same 'impasse' which confronts the petrologist, who is now turning to the exact experiments of physical chemistry for solution of the riddles which confront him."

The use of such terms as vulcanism, volcanic forces and eruptive energy, etc., without understanding what the ultimate cause of these phenomena is, is like using a magic carpet or calling in the services of a fairy queen when we get into a tight place.

In a paper presented to the Institute of Mining and Metallurgy of London, Vol. 18, 1908, I offered for consideration and discussion the results of an effort to explain some phases of the cause of volcanic action and ore deposition. As magmatic water is without doubt responsible for the deposition of our epigenetic ores and as such water is known to have been in a heated condition, the pressure under which it would deposit ore is of great importance. In the discussion of the paper mentioned I showed that by estimating the mean density of steam at the increasing temperature and pressure, and from this deducing the weight of a column of steam from the surface and subtracting the weight of the column of steam from the weight of a column of the rock magma to the same depth, I could estimate the *differential pressure* acting on the steam to force it through the *zone of solid flowage*. The supersaturation of the upper surface of the *zone of solid flowage* resulted from the upward travel of the steam being stopped by the *zone of fracture*. The steam continues to accumulate beneath the zone of fracture under the differential pressure at that depth, and by accumulation gradually acquires the differential pressure of much greater depths. This differential pressure can be shown to increase at the rate of about 2.7 tons per square inch per mile of depth, so that while the differential pressure acting on the steam at a depth of ten miles is 27 tons per square inch, the differential pressure at 100 miles would be about 270 tons per square inch.

The accumulation of the steam beneath the zone of fracture results in elevating the isogeotherms and a thinning of the zone of fracture, and these results assist crushing and folding along

the axis of the ridge in the zone of solid flowage. This results in mountain folding and regional metamorphism by infiltration of silica in solution in the steam, and a reduction of density due to the expansion of the steam and other gases.

The result of this reduction of density is regional elevation which is characteristic of mountain ranges, and the effect of the reduction of density is to make the elevated region lighter and preserve the equilibrium of different regions of differing densities.

Sorby has shown that the depth at which granites have solidified can be estimated by experimenting with the liquid contents of cavities in the granite, and has also estimated the number of these microscopic cavities at as many as one thousand million in a cubic inch.[1] This is the record that the steam has left, and the pores show how the density is reduced.

It is a noteworthy fact that ore-bodies are less frequently associated with extrusive rocks than with intrusive.

The reason for this is easily explained. As I have shown, the tensional pressure under which the steam collects beneath the zone of fracture is in my opinion the ultimate cause of the opening of fissures, the intrusion of dikes, the extrusion of lavas, and the sudden condensation of the steam in the fissure, the cause of earthquakes. When the differential pressure has accumulated until there is sufficient force, the hydrous, fused magma is carried through to the surface and scattered as lava, ash or scoria, and there is no time for a partial separation of the more soluble minerals. But when the pressure on the steam is insufficient to carry the dike through to the surface, then the soluble minerals separate from the mass and are carried up in solution in the condensed steam and deposited in the upper regions of the fracture where the temperature and pressure have been reduced to a point where they cannot be retained in solution.

Lacolithic intrusions are often associated with metallic ores for the same reason, the cause being the difference in time for separation of soluble minerals.

The writer has a photograph of a section of a steel ingot in which the bubbles of gas which was in solution in the liquid steel

[1] Le Conte, p. 234.

have traveled upward and expanded beneath the crust on the top of the ingot and caused little volcanoes to erupt liquid steel until the whole solidified, entrapping the gas which caused the pipe.

Another photograph of a cake of artificial ice shows how the dissolved gases are crowded toward the center of the cake as the freezing takes place from the outside towards the center. The cans of water stand on the bottom of a tank of brine, and the pipes in which the ammonia gas circulates are some distance above the bottom. For this reason the cake is frozen in the middle before it is at the bottom, and the gases dissolved in the bottom are trapped, and the bottom section shows more bubbles than the top. This illustrates how the zone of fracture, which is solid because it is cold, does not allow the steam to pass through like the zone of solid flowage, which is solid from pressure.

Regarding the origin of the gold in the Rand Banket, I believe that the steam or occluded moisture in the magma which formed the dikes was the solvent which deposited the gold and the iron sulphide in the reefs. After the extrusive stage had ceased and the mobility of the magma due to occluded water vapor was insufficient to permit further movement of the mass of the dike, it solidified from the top downward and acted as a plug which prevented the solutions from going through to the surface. The solutions could then seek an outlet through the porous banket and deposit their dissolved minerals by reduction of heat and pressure. Associated hydrocarbons could then deposit graphite in the reef and also precipitate metallic gold from its solutions. The silica in the solutions would be deposited among the pebbles and cement the whole into one compact and impervious mass. By selective action different parts of the reef would thus serve as the channels at different times, and owing to variations in the gold contents of the solutions the reef would be made of different degrees of richness.

The cementation due to the silica contents of the solutions would block up the passage in different parts and force the passage of the solutions in a new channel. Naturally, the bottom reef would serve as the channel of circulation for the greatest

length of time because of the dike solidifying from the surface downward, and that would be the last one to be shut off.

The reason, I believe, why the mineralization is not interrupted by the dikes is that it was contemporaneous and emanated from them, and I think Mr. Denny will find that in regions where the reef is not intersected by dikes, there is no gold. The same is true of the Calumet conglomerate, which is known to occur for a distance of thirty miles or more and only contains copper within two or three miles of that distance, where it is associated with eruptives from which the solutions were derived.

HIRAM W. HIXON.

REVIEWS

Iron Ore Deposits of Vancouver and Texada Islands, British Columbia. By EINER LINDEMANN. Canada Department of Mines, 1910. 27 pages, 5 maps.

Very few of the workings in the iron ores on Vancouver and Texada Islands have progressed beyond the exploratory stage. The principal deposits are magnetite ore found at the contact of igneous rocks and limestones. They probably belong to the pegmatitic type of iron ores —those which have been carried to or near the surface in magmas and have extruded from them, in the manner of pegmatite dikes after the remainder of the magma has been partially cooled and crystallized. Because of this peculiar origin their occurrence is decidedly freakish and the magnitude of the deposits can not be predicted beyond what actually can be observed. Mr. Lindemann makes what appears to be a very candid statement as to the future of these western Canadian ores. He believes that the growing demand in British Columbia for manufactured iron combined with the proximity of the ores to fluxing and fuel materials, will make it highly probable that a pig iron industry will be established on the Canadian Pacific Coast in the future. However, the local market for pig iron is as yet extremely small and the industry if established now would probably have to look to the United States or the Orient for the sale of its products.

EDWARD STEIDTMANN.

Physical and Commercial Geography. By H. E. GREGORY, A. G. KELLER, and A. L. BISHOP. Ginn & Co. Pp. 469, 29 figures and plates.

This book is in three parts. In the first Professor Gregory deals with "The Natural Environment," in the second Professor Keller takes up the "Relation of Man to Natural Conditions" and in the third Professor Bishop treats of the "Geography of Trade." The main purpose of the work, as stated in the preface, is to interpret the facts of trade with reference to man's natural environment. The subject is a fascinating one but so many are the untrodden paths opening before him who pursues it and so rare is the mastery, by any single investigator, of the various branches of knowledge requisite for this broad task that there is little wonder much remains to be done. Here

on common ground meet the geologist, the geographer, the meteorologist, the botanist, the engineer, the historian, the sociologist and many others. Truly the field is vast and the attempt therefore to compass it by a triple alliance in authorship was natural enough. Herein, however, lies the weakest part of the work. There is a good elementary description of the physical features of the earth's surface, there is an interesting discussion of the relation of man to his natural surroundings and there is a readable account of the chief commercial products of the leading countries of the world, but these parts are virtually distinct works and each might have been written independently. Evidently while three differently trained minds could range far and gather much they were unable, because not a unit, to transmute and fuse their materials into the homogeneous intellectual gold that comes from full individual mastery. This is not surprising nor is it a discreditable reflection upon the authors, who point out themselves that they have but broken ground and fully realize how much detail must be omitted in order to keep their work to text-book proportions. They have succeeded in making it readable, suggestive and instructive.

The information given appears to be generally accurate and modern. The geologist and geographer may perhaps question a few statements, such as the one ascribing waterfalls generally to glaciation (p. 88). A moment's thought brings to mind some of the most famous waterfalls of the world flashing through the vegetation of the tropics or situated in regions equally unaffected by glaciation. These blemishes or omissions, however, are not very serious in a work that is generally accurate and bears the stamp of careful writing. The publisher's share in the volume is also a creditable one.

F. L. RANSOME.

Tables for the Determination of Minerals by Physical Properties. By PERSIFER FRAZER and AMOS PEASLEE BROWN. Sixth edition. Philadelphia, J. B. Lippincott Co., 1910. Limp leather. 8vo, pp. xiii + 125. $2.50.

The fact that Frazer's "Tables" has passed through five editions and is now presented in a sixth argues well for its popularity.

The new edition differs very little from the earlier ones. There have been inserted the names and properties of the important minerals discovered since the appearance of the fifth edition but the general plan and arrangement of the two editions are the same. The new edition is printed on better paper than any of its predecessors and is bound in better taste but its price seems unreasonably high.

W. S. BAYLEY.

Petroleum Mining and Oil-Field Development. By A. BEEBY THOMPSON. London, Crosby Lockwood & Son; New York, D. Van Nostrand & Co., 1910. Pp. 362.

A reviewer of this work in the *Oil City Derrick* has said the book has nothing new for the American operator. This statement is probably correct so far as the construction of an American rig and the operation of cable tools is concerned; but this is one of the least important subjects treated in this volume, which until a book of this scope has been issued which is more cosmopolitan in its authorship, must remain a work of great value to oil operators and investors, and one deserving a very wide circulation in all fields. A complete treatment is not to be expected by any one author on the very great variety of subjects as found in all parts of the world touched upon in a work of this kind. The author's object is to offer "a guide to the exploration of petroleum lands, and a study of the engineering problems connected with the winning of petroleum including statistical data of important oil-fields, notes on the origin and distribution of petroleum, and a description of the methods of utilizing oil and gas fuels."

Your reviewer offers the following suggestions as modifications which the writer would have made had he proportionate American experience.

Table 7 on page 10 gives the misleading impression that Kansas is a larger field than Oklahoma. The production of 1907 and 1908 should have been divided between those states as follows:

	Kansas.	Oklahoma.
1907	2,409,521 Bbls.	43,524,128 Bbls.
1908	1,108,781 Bbls.	45,798,765 Bbls.

In the discussion of the leasing of oil lands, the peculiar methods which prevail in Oklahoma and California, the two most productive states in America, should have been described. In Oklahoma a large part of the lands are held by Indians and are leased only on a prescribed form. Each lease must be individually approved by the Secretary of the Interior. On the other hand, in California and the Rocky Mountain states oil lands are largely taken up in pioneer districts as oil placer mining claims, a peculiar and interesting method, which will probably be supplanted by a system of Government permits during the present session of Congress.

Most American students would take exception to the view presented in page 47, that oil in sandstone is generally formed in the beds in which it is found. They generally hold that it originated in shales, where organic matter oxidised less actively than in open sands, and that the oil later migrated to sandstone reservoirs. The light thrown upon the

origin of petroleum by the fact that sand bars and beaches are so frequently associated with lagoons rich in vegetation might well have been brought out.

The statement that all water associated with petroleum strata is highly impregnated with salt is subject to exception in the western states where not infrequently, as in parts of Wyoming, the accompanying water is alkaline rather than salt.

The oil prospects in Alaska referred to in a number of the bulletins of the U. S. Geological Survey are not mentioned. One misses maps of distribution such as those with which Redwood's treatise is so well provided and which now need revision. There is also throughout the book a general failure to utilize graphic devices for expressing statistical data.

Chapters II. and III. give to the reader a disproportionate impression of the importance of asphalt deposits, oil springs, and mud volcanoes as indications to prompt the prospector. In the United States where such a large part of the oil fields are in strata of low dip and well consolidated materials, such indications as these are seldom found. Because of the general low dips such surface indications are often highly misleading and have led to much waste of money.

A proper balance of such a work as this would seem to call for a more detailed discussion of the important matters of effectiveness of asphaltic sealings of exposed oil sands and the various effects of dips and faults. It is very gratifying to find that the author does not make anticlinal structure a *sine qua non*, and that the hydraulic factor is recognized. A more extended discussion of the role of water and of shapes of oil-sand bodies would have been welcome.

The identification of horizons has proved to be an important feature of prospecting in this country since certain horizons have proved productive over wide areas, and certain others wholly non-productive; yet the whole matter of the geologic horizons is almost ignored in this work.

In the comparison of the composition of various petroleums, the very interesting graphic scheme by F. W. Bushong in the Geological Survey of Kansas, Vol. 9, p. 313, might better have been employed. The formula for the interconversion of Baumé and specific gravity determinations should be given with the table on page 144.

Since distillates are so frequently separated at 150° and 300° C. it is of course necessary to compare many of the oils on this basis. It seems unfortunate, however, that in addition to this time-honored basis of comparison that the composition of oils are not also determined on the basis of the specific gravity of the distillate, which is the method commonly used in our refineries. With the present method it is impossible

to call oil below 150° naptha, and that from 150° to 300° illuminating oil, as is so often done in the consideration of these tables.

An important additional use for paraffin in this country is in the manufacture of explosive and water-proof paper.

On page 149 the data on the value of American natural gas could have been replaced by later statistics which would have given a much higher value than shown and would show the very large proportion now yielded by Kansas and Oklahoma.

On page 151 it would have been well to call attention to the remarkable gas of central Kansas which contains such large proportions of nitrogen as to seriously depreciate its quality.

Wooden conductors have very generally been succeeded by drive pipe in the United States. It can no longer be said to be customary to twist the rope at each stroke. The tendency referred to by Mr. Thompson to abandon this practice has now become general in this country. The drilling machine figured on page 224 is very much less used in this country than that of the "Star" type.

On page 276 the impression is given that the perforations are always placed just below the working barrel. The approved method in this field is to place the perforations at the end of a certain length of tubing intervening between the perforations and the working barrel, and with a small hole in the tubing just below the working barrel. The perforations being near the bottom of the hole exhausts the water each day before pumping the oil. The pumping is automatically discontinued by the entrance of air in the air hole when there is danger of the oil sand being exposed and so causing clogging by paraffin.

Of course when the well becomes very small, if the proportion of water is high, the perforations are placed higher in the sand. Or if there is little water the air hole is omitted. On page 296 the method of separating emulsions by steaming might well have been added.

One of the most serious problems awaiting solution in the American high grade oil fields is that of accumulation of paraffin in the wells. This is a question which deserves a fuller treatment than given by the author on page 300. The method there referred to by steaming is not effective in deep wells because of the excessive condensation.

In the recommendation of the drilling of the "pocket" below the oil sand, the author should have referred to the fact that in probably the majority of American wells the lower part of the sand is taken up by salt water which does not make the drilling of the pocket feasible. Yet it is true that an excessive fear of this water on the part of some drillers frequently causes discontinuance of drilling at too shallow a depth.

The spacing of oil wells is a matter of extreme importance and the excessive waste due to close drilling in American oil fields does not receive proper attention. The author might have given tables similar to that which the reviewer has contributed to the *Oil Investors' Journal* of May 20, 1910 (Tulsa, Okla.), to show the areas drained by various spacing of the wells. The important kindred question of the rate of decline of wells, the actual oil content of sands, the extractable percentage, and the distance of effective drainage all call for more exact and extended treatment.

The subject of oil maps and a discussion of the signs, such as is given by the reviewer in ECONOMIC GEOLOGY for April, 1910, would be expected in a work of this scope. A chapter might have been added on the "Economics of Petroleum Mining," discussing the questions of the quantity of oil which may be extracted under various conditions, the cost of drilling and extraction, and the best methods of accounting adapted to the petroleum business.

The table on page 350 for the determination of the volume of gas wells is such an improvement on previous tables for this purpose in this country that it will surely supplant them and be in great demand.

While the very complete bibliography of Redwood makes a duplication unnecessary, it would seem desirable to have added a short select bibliography, and also a fuller one dating from the time that the Redwood bibliography was compiled.

While a fuller treatment was greatly to be desired at several points as indicated, this would have made the volume much larger and more expensive and would have restricted the large circulation that this excellent book so richly deserves. It is to be hoped that the demand will be so great that we may have before long an enlarged and revised edition.

ROSWELL H. JOHNSON.

RECENT LITERATURE ON ECONOMIC GEOLOGY.

COMPILED BY

G. H. LOUGHLIN.

METALLIFEROUS DEPOSITS.

COPPER.

The Yerington Copper District. By J. A. CARPENTER. Min. & Sci. Press. Vol. 101, No. 1, 1910, pp. 4–9.

Outlines location, history, and geology (limestone cut and metamorphosed by granodiorite). Describes ore bodies (pyrite and chalcopyrite superficially oxidized in veins and irregular masses) and the development of the ore bodies at the several mines.

Los Pilares Mine, Nacozari, Mexico. By C. DE KALB. Min. & Sci. Press. Vol. 100, No. 25, 1910, pp. 887–890.

Refers to S. F. Emmons's paper and favors idea that ore body is associated with a volcanic neck, but reaches no definite conclusion. Describes ore and mine-workings.

The Corbin Copper District, Jefferson County, Montana. By F. BUSHNELL. Eng. & Min. Jl.. Vol. 89, 23, 1910, pp. 1154–5.

Quotes statement by E. P. Jennings on geology and ore occurrence (similar to Butte), and describes the different companies.

GOLD AND SILVER.

Gold Deposits of Georgia. By E. K. Soper. Min. and Sci. Press. Vol. 100, No. 26, 1910, pp. 923–924.

A good summary account of the history, location, geology, occurrence of ore and methods of mining. Geologic paragraphs summarize reports by Becker, and others.

Cracker Creek District (Oregon). By J. T. PARDEE. (Abstract from Bull. 380, U. S. G. S.). Min. and Sci. Press. Vol. 100, No. 17, 1910, pp. 585–586.

Condensed description of geology and ore deposits.

The Porcupine Gold District. By H. B. HATCH. Canadian Min. Jour. Vol. 31, 1910, p. 306.

A summary account, devoting one column to geology and ore deposits, and half a column to the promising economic possibilities of the area. The ore deposits, are segregated veins, fissure veins and fahlbands in diorite-schist.

First Year of the Gowganda District, Ontario. By G. M. COLVOCORESSES. Eng. and Min. Jour. Vol. 89, No. 24, 1910, pp. 1218–1219.

Brief discussion of progress of district from a prospecting field to a mining camp. Reviews geology, and compares with Cobalt. The future is still uncertain.

A Silver-Bearing Diorite in Southern Arizona. By J. BOND. Eng. and Min. Jour. Vol. 89, No. 25, 1910, p. 1268.

Quotes petrographic description by F. W. Apgar of a gabbro-diorite containing silver. The silver forms hypidiomorphic crystals, 0.05 to 0.2 mm. in size, included in magnetite, and is believed to be a primary constituent. The gabbro-diorite is associated with an older syenite and later breccias. All but the syenite are cut by silver-bearing veins. The question is raised as to whether the normal gabbro-diorite can be worked for silver.

Old Mining Camp of Pozos, Guanajuato, Mex. By H. A. MEGRAW. Eng. and Min. Jl. Vol. 89, 19, 1910, pp. 961–2.

Gives history, working methods, and occurrence of ores (veins in slate overlain by limestone and soil).

The Geology of the Dolgelley Gold-Belt, North Wales. By A. R. ANDREW. Geol. Mag. April, 1910, vol. VII., No. 550, pp. 159–171.

Gives general geology of the district.

IRON.

Les ressources de la France en minerais de fer. By P. NICOU. Bull. Soc. Ind. Minérale. April, 1910, pp. 305–363.

Describes deposits in Lorraine, western France (Normandy, Anyou, Bretagne), the Pyrenees, and other regions, including French possessions.

Über Sphärosiderite in unmittelbarer Nachbarschaft des Rammelsberger Kieslagers. By B. BAUMGÄRTEL. Centralb. f. Min. Geol. u. Pal. No. 19, 1909, pp. 577–582.

Describes siderite concretions ("spherosiderite") in the so-called "Kupfermeit" near Rammelsberg.

Magnet und Roteisenerzvorkommen in Sudsumatra. By J. ELBERT. Zeit. f. Prakt. Geol. XVII., 1909, H. 12, pp. 509–513.

Le quartz secondaire des minerais de fer oolithiques du Silurien de France et son remplacement en profondeur par du fer carbonate. By L. CAYEUX. Comptes Rendus Acad. Sci. Vol. CXLIX., 1909, pp. 1095–1097.

States that the quartz grains of the oolitic iron minerals are largely secondary, replacing siderite through the action of surface waters. The quartz gradually diminishes and gives way to siderite from the surface downward. L.

Taylor Peak Iron Deposits. By E. C. HARDER. (Abstract from Bull. 380, U. S. G. S.). Min. and Sci. Press. Vol. 100, No. 18, 1910, pp. 615–617.

A condensed description of the geology and ore occurrence, with three geologic maps.

LEAD.

The Cabrillas Lead Mines of Coahuila Mexico. By S. J. LEWIS. Eng. and Min. Jl. Vol. 89, 21, 1910, pp. 1071–1073.

Short sketch of history, geology, development work, origin and character of ore, mining, and possibilities of the mines. Lenses of lead carbonate ore, carrying Ag and Zn, deposited in openings in shaly limestone. Ore zone underlain by a persistent bed of gypsum.

MANGANESE.

Manganerze. By A. HAENIG. Berg.- u. Hutt. Jarb. Bd. LVII., 1909. H. J., p. 121–167.

A general geologic and geographic account, with many analyses of Mn ores.

The Manganese-Ore Deposits of India. By L. L. FERMOR. Memoirs Geol. Surv. India. Vol. XXXVII., 1909.

Part I.: Introduction and Mineralogy. Part II.: Geology (Mode of Occurrence and Origin). Part. II.: Economics and Mining. Part IV.: Description of Deposits.

TIN.

Australia's Premier Tin-Mine. By J. PLUMMER. Min. and Sci. Press. Vol. 100, No. 23, 1910, p. 820.

Tells briefly how a systematic study of the genesis of the ores proved that the Mt. Bischoff mine, thought to be nearly exhausted, is assured of productiveness for several years to come. "Wherever the topazization of the porphyries has occurred, tin is to be found."

On the Origin of the South African Tin Deposits. By R. RECKNAGEL. Trans. Geol. Soc. So. Africa, Johannesberg. Vol. XII., 1909, pp. 168–202.

The cassiterite ore is believed to be a magmatic segregation and a primary constituent of granite.

NON-METALLIC DEPOSITS.

ASBESTOS.

The Quarries of the Canadian Asbestos District. By F. CIRKEL. Eng. and Min. Jour. Vol. 89, No. 18, 1910, pp. 918–920.

One column devoted to occurrence of Asbestos; one to quarries and mills; half column to production and uses; one column to the promising future of Canadian mines.

CLAY.

Prospecting and Testing of Clay Deposits. By E. K. SOPER. Min. and Sci. Press. Vol. 100, No. 23, 1910, pp. 827–830.

Gives classification of clays, a short table of geologic and geographic distribution, mode of occurrence of each, brief hints for prospecting, and descriptions of physical tests and properties.

COAL.

Coal Fields of Northwestern Colorado and Northeastern Utah. By H. S. GALE. Bull. 415, U. S. Geol. Surv. Pp. 265, 1910, 22 plates and 8 figures.

Result of investigations in 1906–7, designed to supplement previous work on the Yampa coal field. Chap. I.: geography, II.: Geology, III.: Grand Hogback field; col. IV.: Danforth Hills field; col. V.: Lower White River field; Col. VI.: Vernal field, Utah; VII.: Western Yampa field; Col. VIII.: Henry Forks field, Utah-Wyo.; IX.: Quality of the coals (mostly high-volatile coals).

The Kansas State Coal Mine. By C. M. YOUNG. Eng. and Min. Jl. Vol. 89, 25, 1910, pp. 1159–1162.

Gives geologic section, composition and preparation of the coal, methods of mining, etc. The mine is worked by convict labor, and coal is furnished free to state institutions. Sanitation, safety and convenience are given more attention than cheapness of operation.

The Northern Appalachian Coalfield. By R. N. HOSLER. Eng. and Min. Jl. Vol. 89, 22, 1910, pp. 1122–1124.

Summarizes general geology, describes the first basin as a whole, and its several coal seams individually.

The Purchase of Coal by the Government under Specifications, with Analyses of Coal Delivered for the Fiscal Year 1908–9. By G. S. POPE. U. S. G. S. Bull. 428, 1910, pp. 80.

Gives in detail the results of government purchases of coal for the fiscal year 1908–1909, and the lists of contracts with abstracts of specifications for the fiscal year 1909–1910, and summarizes the information obtained.

DIAMOND.

Origin of Diamonds in German South West Africa. By R. G. PEARSON. Eng. and Min. Jour. Vol. 89, No. 25, 1910, p. 1282.

Abstract of an article in South African Min. Jour., March 5, 1910. Discards theories for fluviatile and residual origin and upholds that of Merensky and Troye (erosion by and transporting sea currents of pipes or fissures now under the sea, followed by elevation and further distribution by winds).

FELDSPAR.

Economic Geology of the Feldspar Deposits of the United States. By E. S. BASTIN. U. S. G. S. Bull. 420, 1910, pp. 83 with 8 plates.

Gives chemical and physical characters, origin and geologic occurrence, minerals in feldspar deposits, methods of mining and milling, uses, grades, and prices (pp. 5–22). Pp. 23–79 contain locality descriptions.

GRAPHITE.

Uber Graphitlagerstätten. By O. STUTZER. Zeit. f. prakt. Geol. Jg. XVIII., 1910, pp. 10–17.

Describes production of graphite; the geologic and mineralogic characters of graphite deposits. The author differs from Weinschenk in regarding the graphite of the Bavarian and Bohemian deposits as primary constituents in the containing gneiss.

LITHIUM.

Lithium and Its Sources. By F. L. HESS. Min. and Sci. Press. Vol. 100, No. 23, 1910, pp. 822–824.

Briefly explains mode of occurrence of lithia minerals, describes the minerals, and gives two paragraphs on medicinal use.

NITRATES.

History and Review of the Niter Industry of Chile. By M. R. LAMB. Eng. and Min. Jour. Vol. 90, No. 1, 1910, pp. 18–22.

An abstract of a book published in 1908 by Semper and Michels, Santiago, Chile. It is written in Chilean Spanish and contains about 400 pages, with numerous maps and illustrations. It discusses geography, occurrence and questionable origin of the niter; prospecting, mining, extraction, improvements and costs.

OIL.

The California Oil Industry. By C. De Kalb. Min. and Sci. Press. Vol. 100, No. 24, 1910, pp. 857–859.

A brief general account, giving the production of the different districts.

Joint Report on the Bituminous, or Oil Shales of New Brunswick and Nova Scotia; also on the Oil Industry of Scotland. By R. W. Ells. Can. Dept. Mines, Ottawa. 131 pp.

An investigation of the commercial value of the shale deposits of Albert and Westmoreland counties, N. B.

Occurrence and Prospects of Oil in Mexico. By E. Ordonez. Eng. and Min. Jl. Vol. 89, 20, 1910, p. 1020.

A brief note referring to ascension of oil along volcanic vents from a deep seated common source all along the coast. There are oil indications at many places, and the industry is believed to have an attractive future.

The Conditions of Accumulation of Petroleum in the Earth. By D. T. Day. Bi-Mo. Bull. 42, A. I. M. E. Pp. 467–472, 1910.

Summarizes experimental evidence bearing on colors and specific gravities of oils. The differential diffusion of oil through clay is described, and the principle is applied in existing oil fields.

Offsetting Wells. By R. H. Johnson. Oil Investors' Journal. May 20, 1910.

Petroleum Mining. By A. Beeby Thompson. New York, Van Nostrand Co., 1910. Pp. 362.

This excellent manual has chapters on "Geological Structure and Petrographical Character of Petroleum Fields and their Bearing upon the Distribution of Petroleum in the States"; "Indications of Petroleum and Phenomena Associated with its Occurrence"; "Origin, Composition, Characteristics and Treatment of Petroleum" and others devoted to drilling methods, etc. Disproportionate space to Russian conditions and methods.

Drilling for Oil in Eastern Illinois. By R. S. Blatchley. Min. and Sci. Press. Vol. 99, pp. 613 to 617.

An excellent discussion. The new deep Illinois sands are discussed.

Oil Sands of the Mid-Continent Field. By Roswell H. Johnson. Oil Investors' Journal. Vol. 8, pp. 27–28.

A discussion of the application of names to oil sands. A table of the geological formation of the field with its oil sands is given, some of the sands being here first named.

Composition of Oklahoma and Kansas Petroleum. By ROSWELL H. JOHNSON. Oil Investors' Journal. Vol. 8, p. 32.

The analyses made by the U. S. G. S. are here averaged by pools and compared by means of a rough value index.

Methods of Prospecting, Development and Appraisement in the Mid-Continent Field. By ROSWELL H. JOHNSON. Oil Investors' Journal. Vol. 8, pp. 70 to 73, with diagram.

Contains a criticism of methods commonly employed, and urges importance of graphic methods of study of decline of production with examples.

Oil Pools in the Northern Part of the Cherokee Nation at the End of 1909. By ROSWELL H. JOHNSON. Oil Investors' Journal. Vol. 8, pp. 73–75 with map.

Distinguishes between the different producing sands in the several pools.

PRECIOUS STONES.

Tourmaline in California. By J. L. GOWAN. Min. and Sci. Press. Vol. 100, No. 24, 1910, pp. 864–865.

Short historical account, especially of the Himalaya Mine, with description of the mineral, its occurrence, and methods of mining.

SALT, ETC.

Mounds formed by Mineral Crystallization. By F. L. HESS. Min. and Sci. Press. Vol. 100, No. 20, 1910, p. 675.

Describes some low mounds in "Salt Lake" in the Mohave Desert, elevated by the crystallizing of sodium sulphate or of common salt.

Übersicht der Mineralogie, Petrographie und Geologie der Kalisalzlagerstätten. By H. BOEKE. Berlin. Verlag f. bergbaul. u. industr. Fachlit., 1910. 3.50 Mk.

STONE.

Genesis and Classification of Mexican Onyx. By E. M. LAWTON. Min. and Sci. Press. Vol. 100, No. 22, 1910, p. 791.

Expresses the opinion that the onyx marble of Etta in Oaxaca State are the result of alteration of limestone by seepage of surface waters. The process is said to be still going on.

Die Bautechnisch verwertbaren Gesteins- vorkomnisse des Preussichen Staates und einiger Nachbargebiete. By J. HIRSCHWALD. Gebrüder Borntraeger, Berlin, W. 35 Schöneberger ufer 12a.

WATER.

Artesian Waters of the Atlantic Coastal Plain. By M. L. FULLER. A paper read at the twenty-eighth annual convention of the American Water Works Association.

Explains the development of the coastal plain, the source of artesian waters, salt waters, source of artesian pressure, relations of depth to head and volume, temperature of artesian waters, and tidal fluctuations of artesian wells. The principal geologic and artesian water groups of the coastal plain are described, and the quality and utilization of their waters explained.

Surface Water Supply of the United States, 1907–1908. Part XII., North Pacific Coast. Prepared under the direction of M. O. LEIGHTON by J. C. STEVENS and F. F. HENSHAW. U. S. G. S. Water-Supply Paper 252, 1910, pp. 418, with 9 plates.

The paper gives results of importance to navigation, irrigation, domestic water supply, water power, swamp and overflow land drainage, and flood prevention. Pp. 9–31 are introductory and explain various methods of stream measurement, computing, etc. The rest of the report deals with conditions and measurements in special drainage basins.

Surface Water Supply of the United States, 1907–8. Part I.: North Atlantic Coast. By H. K. BARROWS and R. H. BOLSTER. Water-Supply Paper, No. 241, 356 pp., 6 pls. Part III.: Ohio River Basin, by A. H. HORTON, M. R. HALL and R. H. BOLSTER. Water-supply Paper, No. 243, 224 pp., 4 pls. Part IV.: St. Lawrence River Basin, by H. K. BARROWS, A. H. HORTON and R. H. BOLSTER. Water-supply Paper 244, 163 pp., 7 pls. Part V.: Upper Mississippi and Hudson Bay basins, by A. H. HORTON. Water-Supply Paper, No. 245, 133 pp., 5 pls. Part VIII.: Western Gulf of Mexico, by W. B. FREEMAN and R. H. BOLSTER. Water-Supply Paper, No. 248, 171 pp., 4 pls. Part IX.: Colorado River Basin, by W. B. FREEMAN and R. H. BOLSTER. Water-Supply Paper, No. 249, 206 pp., 10 pls. U. S. Geol. Surv., 1910.

REGIONAL REPORTS.

Illinois State Geological Survey. Year-Book for 1908. H. F. BAIN, Director. Bull. No. 14, 1909, pp. viii + 394, 5 plates and 5 figures.

Contains administrative report, by H. F. Bain; report on coöperative topographic survey, by W. H. Herron; studies of Illinois coals, by H. F. Bain and others; coal deposits and possible oil field near Duquoin Ill., by J. Udden; casts of foraminifera in the Carboniferous

coal of Illinois, by R. Bagg, Jr.; natural gas in the glacial drift of Champaign Co., by C. F. Kirk; artificial silicates with reference to amorphous silica, by W. S. Williams; paleobotanical work in 1908, by D. White; proceedings of the Illinois Fuel Conference.

A Reconnaissance of some Mining Camps in Elko, Lander and Eureka Counties, Nevada. By W. H. EMMONS. U. S. G. S. Bull. 408, 1910, pp. 130, 5 plates and 22 figures.

General account of geology, pp. 15–39; of ore deposits, pp. 39–47. Ore deposits are associated (A) with granodiorite intrusives (Cretaceous?) including (1) contact-metamorphic deposits, (2) irregular replacement deposits in limestone, (3) replacement veins and sheeted zones in limestones and shales, (4) fissure veins in quartzite, and (5) fissure veins in igneous rocks; (B) with miocene andesites and rhyolites, including fissure veins and sheeted zones in andesite and fissure veins and fracture zones in rhyolite. Both groups of deposits carry silver, gold, copper and lead. Placers have been worked at some camps. Pp. 47–126 include detailed descriptions of mountain-ranges and mining districts.

Mineral Resources of the Nabesna White River District, Alaska. By F. H. MOFFIT and A. KNOPF, with **A Section on the Quaternary,** by S. R. CAPPS. U. S. G. S. Bull. 417, 1910, pp. 64, 5 plates and 3 figures.

General geography and geology, pp. 7–51; mineral resources, pp. 51–62. Native copper is in placers and in basaltic amygdaloids chiefly as an oxidation product from sulphides, but also as a primary constituent of amygdales. Bornite and chalcopyrite are also found in limestone contact metamorphic deposits, gold of commercial importance, is found in veins genetically connected with intrusive quartz-diorites.

Eleventh Annual Report of the Mining Industry of Idaho for the Year 1909. F. C. MOORE, State Inspector of Mines.

Handbook of British Guiana. Compiled by G. D. BAYLEY. Pub. by Permanent Exhibitions Committee, Georgetown, Demerara, British Guiana. Pp. 608.

Gives information on geology, natural resources, population, and industries.

Bemerkung über einige Erz- und Phosphatbergbaue im zentral Tunis and im Küstengebiet Algeriens. By B. GRANIGG. Oesterr. Zeit. f. Berg. u. Hut.-Wes. Vol. LVII., 1909, No. 49, pp. 739–746; No. 50, pp. 755–761; No. 51, pp. 779–784; No. 52, pp. 793–800.

Short descriptions of a few types of the several ore and phosphate mines.

Die nutzbaren Lagerstätten Koreas. By KATZER. Öesterr. Zeit. f. Berg., Hut., u. Sal.-Wes. Vol. LVIII., 1910, No. 3. pp. 33–45; No. 4, pp. 52–53.

Gold, in veins, contact deposits, and placers, anthracite coal (Jurassic), and brown coal (Tertiary) are the most important. Ag, Pb, Zn, Fe and Cu ores are less important.

Lagerstättensuite von Schneeberg in Tirol und von Brixlegg. By O. STUTZER. III. Jahresber. d. Freiberger Geol. Gesell. Freiberg, 1910, p. 16.

ORE DEPOSITS.

Genesis of Ores. By JOSEPH LE CONTE. Min. and Sci. Press. Vol. 100, No. 23, 1910, pp. 833–834. Reprinted from the same journal, January 24, 1871.

Proposes to show that veins were filled by deposits from hot alkaline solutions. The principal alkali was soda, derived as carbonate from weathering of the soda granites of the Sierras.

Über das Nebengestin der Ramsbecker Erzlagerstätten. By A. DENCKMANN. Jarb. d. Kgl. Prus. Geol. Land.-Anstalt. Bd. XXIX., 1908, T. II., H. 2, pp. 243–253.

Points out that the veins are edel only where they cut graywacke-schist. The explanation offered is that the graywacke-schist was better able to maintain open fractures than were the more yielding clay slates.

Theories of Ore Genesis of Fifty Years Ago. By S. F. EMMONS. Min. and Sci. Press. Vol. 100, No. 21, 1910, pp. 739–742.

An interesting review of work and writings by Whitney, Von Cotta and von Richtofen.

Versuch einer neuen Behandlungsart der Erzlagerstättenlehre. By G. W. H. ADAM. Zeit. f. Prakt. Geol., XVIII., 1, 1910, pp. 5–10.

UNCLASSIFIED.

Faulting in the Bullfrog District, Nevada. By W. H. EMMONS and G. H. GARREY. (Abstract from Bull. 407, U. S. G. S.). Min. and Sci. Press. Vol. 100, No. 26, 1910, pp. 931–933.

An analysis and interpretation of movements in a highly faulted district.

Geologic Bases of Mining Law. By C. DE KALB. Vol. 100, No. 19, 1910, pp. 642–647.

A discussion of the salient features of mineral deposits indicating "that the mining law as it now stands was based upon ideas . . . too

simple to cover the facts as they are found in nature." As regards the law of the apex, "it is an inevitable conclusion that the ends of justice would be subserved by a return to the ancient usage of the common law in real property as applied to mines of all classes."

The Analysis of Silicate and Carbonate Rocks. By W. F. HILLEBRAND. U. S. Geol. Surv. Bull. 422, 1910, pp. 239, with 27 figures. (A revision of Bull. 305.)

Silicate rock analysis: Part I, introductory discussion, pp. 16–40; Part II., methods applicable to silicate rocks, pp. 41–204. Carbonate rock analysis: Part I., introductory discussion, pp. 205–211; Part II., refined methods of analysis, pp. 212–228; Part III., condensed analysis.

Analyses of Rocks and Minerals from the Laboratory of the United States Geological Survey, 1880–1900. By F. W. CLARKE. U. S. G. S. Bull. 419, 1910, pp. 317.

Pp. 1–4, introductory; pp. 4–11 discuss the average composition of rocks. The balance of the work records analyses, with petrographic summaries, of all analyses made in the survey's laboratory. Analyses of igneous and crystalline rocks, sandstones, cherts, and sinters, carbonate rocks, slates and shales, clays and soils, and meteorites are grouped separately and arranged according to states. Mineral analyses are grouped according composition (sulphides, carbinates, silicates, etc.).

SCIENTIFIC NOTES AND NEWS[1]

FRITZ CIRKEL, of Montreal, acting as consulting engineer for the "Dominion Goldfields of Canada Limited" was engaged during the summer in a thorough investigation of a large territory of gold gravels in the county of Beauce, Quebec. Four power drills are in operation to test a number of river bars, specially those of the Gilbert River, the Ruisseau des Meules and the Chaudiere River. Operations have been in progress since October last; a California expert is superintending the work, and it is reported that several extensive gold leads have been located. This district was worked spasmodically from 1865 to 1885, but owing to inadequate methods and continuous litigation the deposits have never been investigated or exploited to their full extent.

PROFESSOR C. K. LEITH, of the University of Wisconsin, sailed from New York on July 6, by way of England, for South America, where he was engaged in professional work for several months. Mrs. Leith accompanied him throughout the trip, and his two sons went as far as England. Mr. E. C. Harder, of the United States Geological Survey, Washington, D. C., accompanied Professor Leith as assistant.

MR. HENRY LEIGHTON has resigned his position as assistant in economic geology, New York State Museum, to become instructor in mining geology in the School of Mines, University of Pittsburg.

L. S. GRISWOLD has resigned the chair of geology at the Missouri School of Mines. Professor Griswold intends to give his entire time to consulting work.

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

PROFESSOR GUY HENRY COX, formerly assistant professor of mineralogy and petrography at the Missouri School of Mines, has been placed in charge of the department of geology and mineralogy at that institution.

MR. J. W. EGGLESTON has been appointed assistant professor of geology and mineralogy in the Missouri School of Mines. Mr. Eggleston is a graduate of Amherst and of Harvard and has had an extensive experience in teaching geology and mineralogy in the Colorado School of Mines and Harvard University. Professor Eggleston will enter upon his new duties September first.

AN INTERNATIONAL American Scientific Congress was held in Buenos Aires, Argentine Republic, July 10–25, 1910.

THE FOLLOWING is an outline of the work now in progress under the direction of the director of the *Mines Branch*, Dominion of Canada:

1. Investigation of iron ore deposits and magnetometric surveys in New Brunswick, at Bathurst; in Quebec of the magnetic sands on the north shore of the St. Lawrence; and in Nova Scotia in the Nictaux-Torbrook basin.

Mr. E. Lindeman and Mr. Howells Fréchette, with two technical assistants.

2. Continuation of the investigation of copper and pyrite deposits for the preparation of a monograph on the copper resources of Canada. This season the work will be carried on in Ontario and in the maritime provinces. If time permits it is also proposed to investigate the commercial processes for utilizing the sulphur content of pyrite ores and to prepare a special bulletin on this subject. Pyrite burning is of especial importance at the present time, with respect both to the sulphite pulp industry and to the preparation of mineral fertilizers. At the present time Canada imports native sulphur and exports her pyrite ores.

Dr. Alfred W. G. Wilson.

3. Continuation of the investigation of the molybdenum deposits of Canada, to complete the work and to prepare a monograph on the subject.

Dr. T. L. Walker.

4. Report on the building materials of Canada—work to be carried on in Ontario during 1910.

The building materials of Canada have been greatly neglected. At the present time large quantities of stone and other materials are imported from foreign countries, equally suitable stones occur in Canada. It is proposed to prepare a series of special bulletins on Canadian resources of this kind. The first of the series is to be a report on the more accessible supplies of building and ornamental stones in Canada.

Dr. W. A. Parks.

5. Monograph on mica, second edition.

The first edition of the monograph on mica, published in 1905, was exhausted long ago, but applications are constantly being received for copies. In preparing a second edition additional field work is necessary to bring the report up to date.

Mr. Hugh de Schmidt.

6. The investigations upon peat are being continued at the Fuel Testing Plant. Certain types of gas producers in the United States are also to be examined for the purpose of selecting a suitable producer for lignite and bituminous coal for installation at the testing station.

Mr. B. F. Haanel.

7. Operation of the government peat bog at Alfred for a period of about three months to demonstrate the latest process of manufacturing air-dried peat. Several thousand tons will be produced during the present season. Part of the peat fuel produced will be shipped to Ottawa for use in the department's peat-gas producer plant and part will be sold in the neighborhood for domestic use.

Mr. A. Anrep.

8. Continuation of the investigation of peat bogs in Canada to ascertain their extent and to determine the quality and quantity of peat available.

Mr. A. Anrep and an assistant.

9. Collection of special supplies of fuels and ores from various

localities for experimental work to be conducted at the Fuel Testing Station and ore dressing laboratories.

Staff officers.

10. Installation of an ore dressing plant at the testing station, and an experimental investigation into methods of concentrating certain iron ores.

Mr. G. C. MacKenzie.

11. A special investigation of the plants where explosives are manufactured and stored, to gather information with respect to the conditions now prevailing in Canada.

Mr. Joseph G. S. Hudson.

12. Special investigation and recommendations with respect to the establishment of an explosives testing station in Canada and with respect to the regulation of the manufacture and storage of explosives.

Probably, Captain A. P. H. Desborough, of the Home Office, Great Britain.

13. Officers of the Division of Mineral Resources and Statistics will visit mining districts in various parts of the dominion for the purpose of collecting statistics of mineral production and of securing information of general interest relating to the mining industry, including a record of new and recent developments, and data as to character of ores and products, prices, markets, and demand for various mineral products.

14. An investigation of recently invented processes in Europe for the production of spelter and zinc oxide, by F. W. Harbord of London, England.

15. Investigation and experimentation for the purpose of developing a process or processes for the utilization of the zinc ores of Canada in the production of spelter and zinc products in Canada.

Experts to be engaged.

16. Investigation of metallurgical problems of economic importance at School of Mines, Kingston.

Special expert to be engaged.

THE work which has been carried out by the *Geological Survey* of Canada during the past summer is as follows:

Mr. D. D. Cairnes has been examining the ore deposits of the Atlin District, British Columbia.

Mr. R. G. McConnell, assisted by G. O. Malloch, has been studying the country at the head of the Portland Canal. Attention has recently been drawn to the mineral deposits of this district.

Mr. W. W. Leach has been continuing his explorations in the Hazeltown District, along the line of the Grand Trunk Pacific Railway, on the Skeena River.

Mr. C. H. Clapp has been continuing his geological investigation on the southeast end of Vancouver Island.

Mr. R. H. Chapman has been continuing topographical work on Vancouver Island.

Mr. Chas. Camsell has been completing the geological mapping of the Tulameen District, British Columbia.

Mr. L. Reinecke has been continuing the mapping of the Beaverdell District, West Fork Kettle River, British Columbia.

Mr. O. E. LeRoy has been completing his study of the geology and ore deposits of the Slocan District and investigating Deadwood Camp, Boundary Creek district, British Columbia.

Mr. W. H. Boyd has been engaged in topographically mapping these districts.

Mr. R. Schofield has been continuing his work in East Kootenay, British Columbia.

Mr. J. Allan has been making a geological study of the Ice River District, British Columbia.

Mr. Shimer will investigate the Devono Carboniferous, along the main line of the Central Pacific Railroad in the Canadian Rackies.

Mr. D. B. Dowling has been continuing his investigations of the coal areas of Alberta along the line of the Grand Trunk Pacific Railway.

Mr. W. McInnes has been exploring in the country north of Prince Albert, Saskatchewan.

Mr. H. Ries and J. Keele have been engaged in a study of the clay deposits of the Northwest Provinces.

Mr. J. D. Trueman has been making a geological survey of the district about Gunflint Lake, Ontario.

Mr. W. H. Collines has been engaged in a geological study of the country west of Gow Ganda, Ontario.

Mr. W. A. Johnston has been completing his mapping of the Lake Simcoe District, Ontario.

Mr. C. R. Stauffer has been making a detailed study of the rocks of the southeastern peninsula of Ontario, in view of the occurrence of oil, gas and salt in this region.

Mr. M. E. Wilson has been exploring the country near the Transcontinental Railway east of Lake Abitibi, Quebec.

Mr. J. Dresser has been continuing his investigations in the Eastern Townships of the Province of Quebec.

Mr. E. R. Faribault has been spending part of the season in the Chibougamou district as a member of a geological commission sent out by the Quebec Government, and devoted the remainder of the season to a study of the gold-bearing series in the Lunenburg district, Nova Scotia.

Mr. J. W. Goldthwait has been studying the Pleistocene geology of the St. Lawrence valley.

Dr. G. A. Young has been making a geological survey of the Tobique district, New Brunswick.

Mr. M. Y. Williams has been engaged in a detailed geological investigation in the Arisaig district, Nova Scotia.

Mr. R. W. Ells has been examining a reported coal occurrence in Gaspé and mapping in detail the richer banks of oil shale in New Brunswick.

Mr. J. Macoun with Mr. C. H. Young has been collecting marine fauna of the Atlantic coaest for the New Victoria Museum.

Mr. Jas. Macoun has been studying the fauna about Fort Churchill, Hudson's Bay.

WORK on the stately new Victoria Museum at Ottawa, which will house the Geological Survey, is approaching completion and it is expected that the building will be ready for occupancy next fall.

The work of the geological survey is being largely reorganized. A topographical division has been established, with W. H. Boyd as its chief. Heretofore the geologists of the survey have been very seriously handicapped by being called upon to prepare the topographical maps necessary for their work. A staff of topographers is now being trained, who will prepare maps of all districts in which geological work is to be done. To assist in the organization of this division and in the training of a corps of topographers, the United States Geological Survey has generously consented to allow Mr. R. H. Chapman, one of the most expert topographers of its staff, to spend two years in the service of the Canadian Survey.

Dr. Percy Raymond, of the Pittsburg Museum, and formerly professor of invertebrate paleontology at the Pittsburg School of Mines, has been appointed to a position on the staff. This will greatly strengthen the paleontological work of the Canadian Survey.

Committees have also been organized having special supervision over the maps and reports issued by the survey. The maps have been standardized as to form and detail and the appearance of all the publications of the survey has been greatly improved. The committee in charge of the maps consists of Messrs. C. O. Senecal, W. H. Boyd, D. B. Dowling and A. Dickson. The committee in charge of reports consists of Messrs. R. G. McConnell, W. McInnes, O. E. LeRoy and G. A. Young. The director is an ex-officio member of all committees.

It has been found that as the work of the survey accumulates year by year an immense amount of detailed knowledge of the minerals and geology of the country, the literature becomes so voluminous that important facts are liable to become buried under the mass of detail. The survey is consequently issuing a series of special reports on particular subjects, compiled from the information which the survey has gathered. One of these, on the "Coals of the Northwest Provinces," has recently been issued by Mr. D. B. Dowling; another on the "Gold-bearing Rocks of Nova Scotia" is about to go to press. Other similar reports will be issued as rapidly as possible.

A descriptive sketch of the geology and economic minerals of Canada, compiled by the director and Dr. Young, with the assistance of other members of the staff, has recently appeared.

STATE GEOLOGICAL SURVEY OF TENNESSEE.

The State Legislature of Tennessee, at its last session, provided for the establishment of a geological survey to begin operations the first of the present month. The bill provided for a State Geological Commission, composed of the Governor, the State Commissioner of Agriculture, the Chief Mine Inspector, the president of the University of Tennessee, the chancellor of Vanderbilt University, and the vice chancellor of the University of the South. This commission has held several meetings, and on March 16 elected as state geologist, Mr. George H. Ashley, formerly of the U. S. Geological Survey, and as associate geologists, Mr. L. C. Glenn, of Vanderbilt University, and Mr. C. H. Gordon, of the University of Tennessee.

The new survey began its work May 1, as provided by law, the survey office being established for the present in the capitol annex building, Nashville. Before beginning work regularly Mr. Ashley had made provisional arrangements for a large amount of coöperative work with several of the national bureaus, so as to nearly double the money to be spent on the geology of the state.

The main publications of the survey will probably appear as bulletins to be issued as fast as work is completed. Among the things with which the new department will concern itself may be mentioned coal, oil, gas, ores, fertilizers, building stones, road-making materials, clays, cement materials, sands, solid minerals and artesian waters, drainage of swamps, streams, and water powers, and other natural resources. Manifestly with the funds at its command, it will be impossible for the survey to take up all of these matters at once, as, aside from certain preliminary studies, it is planned that all of the work done shall be as thorough as any similar work being done by either the national or the other state governments. Such work is slow and expensive, but ex-

perience has everywhere demonstrated that such thorough work repays the extra cost many times over.

The survey is anticipating the hearty coöperation of citizens of the state wherever its work is carried on. It would also appreciate any information bearing on its work—the discovery of new deposits and the extension of the area of known deposits of minerals or ores or any facts bearing on the subjects already enumerated; in its turn the survey stands ready to supply all the information it can along these same lines. While it cannot undertake to analyze specimens, or to make assays of ores, it would gladly make such an examination of specimens as can be made wihtout analysis or assay.

Again, in the prosecution of the field work, much information of a confidential nature will be obtained. Such information will be held strictly confidential, and will not be made public, through publications or otherwise, except on the expressed permission of those supplying the information.

It is planned, by notices in the newspapers, to keep the public informed of the results of work going on, or of any publications ready for distribution.

REALIZING THAT THE "HINTERLAND" of the province of Quebec offers great possibilities from the standpoint of mineral resources, the Quebec government decided to take steps towards exploring a region which has attracted great attention during the past few years. Accordingly a large geological party has been sent this year in the Chibougamau Lake District, with instructions to report, as exhaustively as is possible in one season of field-work, on its geology and the mineral deposits.

The Chibougamau region lies about 200 miles to the northwest of Lake St. John, immediately south of the 50th degree of latitude and west of the 74th degree of longitude. According to the reports of previous explorers, such as Richardson in 1870, Low in 1885 and 1905, Bell in 1896, Obalski in 1904, the country is occupied by an important development of Huronian rocks, which in places are very strongly mineralized. Prospectors have

brought back from this district good specimens of copper ores, of iron ores, gold-bearing quartz and asbestos.

However the lack of means of transportation militates against the rapid development of the country, and the provincial government has been urged to take steps towards remedying this by building a railway into the region or by granting subsidies to a company.

All the information available on this region is the result of exploration work on broad lines rather than of detailed examination, and before taking any steps which might involve an expenditure of several million dollars in the construction of a railway, the provincial government very wisely decided to send in a commission of geologists and mining engineers to obtain more specific data as to the mineral possibilities of the region.

The party which left Roberval, on Lake St. John, at the beginning of June is composed of three commissioners, with technical assistants, and twelve men who will do pick and shovel work, drilling and blasting when necessary.

The three commissioners appointed are: Dr. A. E. Barlow, of McGill University, a mining geologist, who has specialized in the study of Archean rocks; Mr. J. C. Gwillim, professor of mining engineering at Queen's University, Kingston, and Mr. E. R. Faribault, one of the senior officers of the Geological Survey of Canada.

The region in question comprises an area of about thirty miles by twenty, to be mapped geologically, and within this area several patches of rocks known to be strongly mineralized will be examined in greater detail, as well as any other points which might be deemed worthy of attentiion.

The report of the commission will be published as soon as possible after the return, which will be in the latter part of September.

AT THE Eleventh International Geological Congress, held at Stockholm from August 16 to 25, the United States Geological Survey was represented by Director George Otis Smith and by

Messrs. S. F. Emmons, George F. Becker, Whitman Cross and Waldemar Lindgren.

Professor John D. Irving also attended the Congress at Stockholm and afterwards visited ore deposits in Scandinavia and Germany in company with Mr. Lindgren.

IN AUGUST Mr. J. B. Tyrrell, of Toronto, Canada, left for a short visit to London, England. His address in London will be "Mining and Metallurgical Club, St. Ermin's, Westminster, London, S.W., England."

THE FOLLOWING RECENT GRADUATES of Ohio State University have received appointments to positions in geology: D. Dale Condit, as assistant in geology for the ensuing year in Columbia University. Jesse E. Hyde has been reappointed an assistant in geology in Columbia University. Next year during the absence of Professor Grabau, Mr. Hyde will give the instruction in several of the classes. Clara G. Mark, as instructor in geology for the ensuing year in Mount Holyoke College, Massachusetts. Wm. C. Morse has been reappointed instructor in geology in Ohio State University. Clinton R. Stauffer, Ph.D. '09, Chicago University has been elected assistant professor of geology in Queen's University, Kingston, Ontario. This position also carries with it an appointment on the Canadian geological survey for field work during the summer. For the present year Dr. Stauffer has been assigned to study the Devonian rocks of Ontario.

C. W. WRIGHT, who is managing mines in Sardinia, is at present in Washington, completing a report on the Kasaan Peninsula, Alaska, for the U. S. Geological Survey.

RECENT APPOINTMENTS in the School of Mines of the University of Pittsburgh are as follows: Horatio C. Ray, instructor in metallurgy, Harry N. Eaton, instructor in geology and petrography, Henry Leighton, instructor in mining, geology, and mineralogy, Harry B. Meller, instructor in mining.

PROFESSOR L. S. GRISWOLD has resigned the chair of geology at the Missouri School of Mines, to give his entire time to consulting work. Professor Guy Henry Cox, formerly assistant

professor of mineralogy and petrography, has been placed in charge of the department of geology and mineralogy. Mr. J. W. Eggleston has been appointed assistant professor of geology and mineralogy. He is a graduate of Amherst and of Harvard and has taught geology and mineralogy in the Colorado School of Mines and Harvard University.

UNDER AN APPROPRIATION transferred from the General Land Office to the U. S. Geological Survey, several parties under the supervision of Hoyt S. Gale are classifying a considerable area of Northern Pacific Railway land grants in Idaho and Montana. Three parties in the St. Joe country, northern Idaho, are in charge of F. C. Calkins, Malcolm McDonald and E. E. Smith, and R. W. Stone has a party in the Elkhorn Mountains, south of Helena, Montana.

THE EXAMINATION of the Powder River coal field in northeast Wyoming, which has been in progress since 1907, is being continued this year by four parties. C. H. Wegemann is working between Trabing and Casper, Dean Winchester in northeast of Douglass, V. H. Barnett south of Gillette, and J. A. Davis on Little Powder River north of Gillette.

W. R. CALVERT has charge of six parties determining the limits of the coal field in eastern Montana. These parties are under the immediate direction of A. L. Beekly, E. Stebinger, M. A. Pishel, J. H. Hance, F. A. Herald and C. F. Bowen.

HENRY HINDS has undertaken the examination of coal fields in northern Missouri.

C. T. LUPTON is examining coal lands near Vernal, Utah